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SOME LITTLE EMPHASIZED GUIDE-POSTS TO MEDICAL ENTOMOLOGY.*

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To address the members of the Entomological Society of America on the subject of the history of medical entomology may seem a needless presumption. Immediately when the topic is mentioned there occurs the thought that medical entomology is a branch of our favorite study too young to have a history.

The discoveries of the relations of insects to disease which have revolutionized the attempts to control some of the most devastating diseases of man and animals have been made within the memory of even the younger in this audience. So spectacular have they been in some instances, and so far-reaching in their application that they have been featured by the popular magazines and by the daily press. Today it is common knowledge that many diseases, whose origin and spread were shrouded in mystery a few short years ago are insect borne.

It is often said that these discoveries have all been made within the past twenty-five years. And yet, the worker in science knows that no new discovery—no pregnant theory—originates suddenly. There is no more a spontaneous generation of important scientific theories, uninfluenced by pre-existing knowledge and thought than there is spontaneous generation of the higher forms of life.

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To trace the development of science, or some particular phase of a science is not a mere idle amusement. Regarding history Emerson has said it is "A looking both before and after as, indeed the coming Time already waits unseen, yet definitely shaped, pre-determined and inevitable, in the Time come; and only by the combination of both is the meaning of either completed." So, too, in the field of biology the discovery of today is but the fruitage of a tree rooted deep in the past. And this fruitage in turn though many of its seeds may fall by the wayside will yield the germ from which will come still better fruit.

Many workers have already called attention to early suggestions or even carefully worked out theories regarding the relation of insects to disease. In some cases these suggestions have been over-valued, through being interpreted in the light of present day knowledge. In some instances it is evident that a keen pioneer worker had grasped and all but established the truth which was first to be accepted many years later.

Yet these suggestions were largely lost sight of, and lay dormant for decades and even for centuries. Why was not this also the fate of the suggestions of twenty-five years ago? The answer lies in the history of zoology, and it is this general topic in its relation to medical entomology which I wish to touch upon tonight. This phase I have already presented in outline in an earlier discussion.

The subject is a broad one—it might well serve as the occasion for pointing out that there are no unrelated truths and that all branches of science contribute to genuine advancement in the field of human knowledge.

It is obvious that the work of Pasteur and Koch, resulting in the development of the science of bacteriology, has had a most intimate and profound influence in bringing about an understanding of the role which insects and their allies play in the transmission of disease.

However much the influence of modern bacteriology is recognized, it is not so generally known that from the time of the discovery of bacteria by the Jesuit priest, Athanasius Kircher, in 1658, and by Leeuwenhoek, there was a period of over a century when the germ theory of disease was the dominant one in medicine and most profoundly affected workers in

biology. Though this influence was an intangible one, it must nevertheless be reckoned with. However important this intangible influence may have been and however fundamental bacteriology has been to the development of medical entomology, the outstanding guide-posts of a century and more ago were in the field of helminthology, or the study of the grosser parasites of man and animals.

We laugh today at the crudities of the early zoologists who taught in the most matter-of-fact manner, amazing theories of heterogenesis, according to which the offspring of a given animal may be something utterly different from itself. However deeply ingrained they were in the popular mind, theories of the development of geese from barnacles, or of the spontaneous generation of frogs from mud, of mice from grain, and of bees from dead oxen were discarded by the advanced scientists of the 17th century.

Much more slowly did this changed viewpoint apply to the various helminths or intestinal worms. We know that Redi with all of his keenness and daring was unwilling to commit himself to the view that the endo-parasites of animals might not originate spontaneously. It is more surprising to find that as late as 1819 the noted parasitologist Bremser presents a careful, and, for the period, convincing argument in favor of the spontaneous origin of these forms. The noted medical treatise by Roche and Sanson, in 1828, declares that the opposing view according to which the helminths are transmitted from animal to animal, being introduced into the body through the air, or food, or drink, demands such a measure of credulity that it is surprising that it has found any defenders.

But even as Bremser wrote he and scores of indefatigable workers were accumulating data which were to completely reshape the attitude of the zoological and medical world towards these parasites. In the first place, there was a growing recognition of the fact that the grosser parasites which, from the time of the ancients, had been known to occur in the bodies of man and animals, did not constitute a group absolutely apart, but were animals subject to the same fundamental laws of development as were free-living forms. Thus helminthology, or the study of parasitic worms was recognized as having more than medical interest, and attracted the attention of leading zoologists of the period.

To these workers it was no longer sufficient to explain the occurrence of a tapeworm as due to spontaneous generation from the slime or mucus of the intestine or from the digested food. As early as 1776 Pallas had called attention to the fact that within the little bladders or cysts which occurred within the liver tissue of the mouse there was a jointed worm whose head structures were wholly comparable with those of tapeworms to be found in the intestine of cats. In 1851, the problem was solved by Küchenmeister who proved by experimental feedings that similar bladders from the viscera of rabbits developed into complete tapeworms when fed to dogs. This introduction of the experimental method is justly regarded as the basis of our modern conceptions of the development of internal parasites.

Parallel with and in some important conceptions preceding this discovery of the typical life cycle of a tapeworm was the interpretation of the still more complicated life cycle of the liver fluke. So universally is this form used in class work that we forget the marvel of the story. The steps that led up to its solution are rarely mentioned:

Baker, Adams, and other early microscopists had figured little tadpole-like organisms which they found rarely in pond-water. In 1773, O. F. Muller constituted for these the genus *Cercaria*, which in the light of his times he naturally placed among the Protozoa. It seems to have escaped notice that before 1680 our old entomological friend, Swammerdam had found similar organisms and what we know today as rediæ, in the snail and had figured them.

In his work on the anatomy of "the wonderful viviparous chrystalline snail," as he calls *Paludina*, he tells us that the uterus of the snail "I immediately met under its upper coat which it has in common with the coat of the verge, a congeries of oblong little parts (Fig. vii, a) which were very numerous, and differed somewhat in their length, figure and thickness, and when I removed them from their places, I found they were all alive, and were so many living little worms, as there appeared particles of that sort. On the inside of these worms was seen an oblong transparent ash-gray colored furrow or ridge. When I began to dissect one of these worms, two, nay three, and sometimes four inclosed worms of the same kind issued forth

having almost the same figure, that is, a thick head, Fig. viii, a, and *a* small tail *b*, like young frogs or tadpoles." Swammerdam well adds: "I must confess the sight of these astonished me, as I never expected to have met such, and so many miracles in one little creature, or that I should have been so well convinced of my own ignorance and blindness in a single subject."

In 1831 Mehlis made the remarkable discovery that the eggs of certain flukes "contained an embryo which in shape and ciliation resembled an Infusorian; it was occasionally provided with an eyespeck and after being hatched swam about like an Infusorian." (Leuckart.)

The discoveries of Swammerdam, a century and a half before might well have formed a link in the chain, but this link was to be formed anew by Bojanus and by Von Baer. In 1818 Bojanus described brightly colored worms which we now know as rediæ, in pond snails. Von Baer in 1824 showed that these rediæ give rise in their interior to the above-mentioned tailed cercariæ which, becoming free, swim about in the water.

Numerous other workers contributed observations but it remained for Steenstrup to correlate and interpret the data. He pointed out that the embryo escaping from the egg became the free-swimming larva, that this entered the snail and formed a generative sac (the sporocyst) which gave rise to rediæ. From these in turn arise cercariæ which developed into the adult flukes. Remarkable advances in the study of the flukes have been made since 1842, when Steenstrup published his conclusions but the essential facts were made clear by him. It is worth pausing to note that these facts which are fundamental to any control measures against some of the most dangerous of the parasitic worms were obtained through work on forms of no economic importance.

The early workers on insect anatomy occasionally noted the presence of parasitic worms within their specimens. Reference to such are found in Roesel, DeGeer, and Reaumur. The earliest which I have seen is that of Lister who in 1672 not only demolished the view that horse hairs gave rise to snakes, but showed that the so-called "hair-snake" lived for part of its life within "Black-beetles." Von Linstow's epochal studies on the development of Gordius were on a species found in *Pterostichus niger*, possibly this same "black beetle."

As the interest in helminthology grew these scattered references were rapidly multiplied. This is not surprising when we consider the amazing diligence with which the early workers on animal parasites pushed their work. Ten years before his death Bremser wrote that he had with his own hand dissected over 25,000 animals in search for endo-parasites. The collection under his direction, which he was constantly working over, contained specimens from 50,000 hosts.

Rudolphi in 1819 lists 29 species of insects in which had been found nematode worms. Von Linstow 1878, in his Compendium der Helminthologie, lists 220 insect hosts and to these he added 43 species in his "Nachtrag" of 1889.

Some of the most significant of the observations along this line were made by Stein, in the course of his comprehensive work on the female reproductive organs, published in 1847. He found many instances of larval nematodes and cestodes encysted in his specimens.

In a most significant paper, published in 1853, he calls especial attention to these finds and suggests that the larval worms which he found were taken up with their insect host by some other animal in which they reached maturity. His most noteworthy discovery was that in the body cavity of the meal-beetle, *Tenebrio molitor* and its larvæ, there were occasionally to be found numerous microscopic cysts enclosing a tapeworm-like head. These he found in all stages from the recently liberated embryo to the completed cysticercoid, and he suggests that they might be the larvæ of a tapeworm of cats, dogs, rats or mice, or even of man. In the light of our present day knowledge, there is every reason to believe that Stein had found the larval stage of *Hymenolepis diminuta* of rodents and occasionally of man. As we shall see later this tapeworm has as intermediate host a variety of insects, including Tenebrionid beetles.

The first complete life cycle of a parasitic worm involving an insect as intermediate host seems to have been worked out by Leuckart in 1867 for *Protospirura muris* (Spiroptera obtusa), a small, round worm found in the stomach of mice. The eggs of this worm are discharged with the droppings of mice, and are picked up by meal worms and the escaping embryos make their way to the body cavity of the larva and become encapsuled, there to remain until the insect is eaten by a mouse, within

which the worm can mature. This case has acquired added significance through recent discoveries that a related worm, developing in the cockroach, is capable of causing cancer of the stomach in rats.

Two years later, in 1869, Leuckart and his student Melnikoff, discovered in the body cavity of the dog louse, cysts which proved to be those of the double-pored tapeworm of dogs, the commonest species infesting these animals. In reality, the worm infestation is more common than is the louse infestation, a fact which was puzzling until 1888, when Grassi found that the dog flea also serves as an intermediate host for the worm. The cysts are so minute that as many as fifty have been found in a single flea. The dog becomes infested solely through swallowing an infested louse or flea. In rare cases this tapeworm is also found as a human parasite, usually in children.

We have seen that Stein early suggested that insects might serve as intermediate hosts for tapeworms of various animals. Of a number of such cases worked out may be cited that of *Hymenolepis diminuta*. This parasite of rodents and occasionally of man is noteworthy for the number and wide range of arthropod hosts in which it may develop. There have been reported the meal-infesting lepidopter *Asopia farinalis*, the Forficulid, *Anisolabis annulipes*, two tenebrionid beetles and three fleas. Recently, there was brought to my attention evidence that the larvæ of this same tapeworm may develop also in myriapods.

An exceedingly common disease in many tropical and subtropical countries is elephantiasis, a disease marked by an enormous swelling of the extremities or affected parts. An apparently isolated endemic center is Charleston, S. C. Typical cases are shown by the lantern slides, the second of which is from a Japanese makimona of the 12th century. Though several conditions may give rise to this disease, it is most commonly due to the presence in the lymphatics of parasitic roundworms, upwards of four inches in length. These discharge living larvæ which are to be found in the blood stream. The life history is especially significant because it is that of the first human parasite found to be dependent upon a mosquito for its development. The larvæ were first noted in 1863, and in 1872 Lewis recognized that the blood of man was their normal habitat and

gave to them the name *Filaria sanguinis hominis.* In 1876 Manson discovered the adults and in the following year he and Bancroft simultaneously suggested that they underwent a part of their life cycle in mosquitoes. This fact was very soon demonstrated by Manson, though many of the details have since been worked out.

The larvæ occur in myriads in the blood of the affected individual but are found in the peripheral blood only at night. They are taken up by feeding mosquitoes and within the body muscles of the insect must undergo a development before they are capable of further development in man. In about three weeks they leave the muscles of the mosquito and settle down in its mouthparts, there to await the visit of their host to man. When the mosquito now feeds the larvae are not injected, but escape from the proboscis of the mosquito and actively bore into the skin of their new host, as does the hookworm. In this respect the procedure differs from that of malaria, in which the spores are directly injected by the mosquito.

A related filarial worm *Filaria immitis* lives as adult in the heart of the dog. In this as in the preceding species the larvæ are discharged into the blood and are taken up by mosquitoes. From the stomach of the insect they pass to the excretory or Malpighian tubules, and undergo their metamorphosis there instead of in the muscles. In about two weeks they are ready to enter the dog in the same manner as the preceding.

The guinea worm, *Dracunculus medinensis*, is a filiform parasite of man, upwards of three feet in length, which lives under the epidermis, usually in the leg or foot. Over the vulva of the worm a small hole opens through the epidermis to the surface and through this the microscopic larvæ escape.

The presence of the worm and its products often leads to very severe inflammation, to abscess and sloughing, and even death from secondary infections. The usual method of extraction practiced by natives where the parasite is endemic is to wrap the protruding worm around a stick which is every day given a turn or two until the entire worm is drawn out. The parasite has been known since very remote periods. An illustration in Pigafatta's account of his voyages to the Congo show that this method of extraction was practiced there in 1598. Agitharchides, 150 years B. C., gives an account of the disease

as seen on the shores of the Red Sea. It has even been suggested that the fiery serpents which attacked the Israelites in the desert were guinea worms and that Moses set up the serpent on the stick as an illustration of the method of extraction.

As is to be expected, many theories as to the origin of this famous parasite were proposed. Mercurialis, the Italian physician who about 1590 so clearly outlined the theory of the carriage of contagion by flies, ventured again into medical entomology, when he suggested that the guinea worm was contracted from eating grasshoppers. Others believed it identical with the "*Gordius aquaticus*" or hair snake. It was often maintained that infection was conveyed through drinking water and probably many a traveler followed the example of Baron von Jacquin who declared "Well, then, I'm safe enough for I shall not drink a drop of water." We read that in spite of his self-denial he was the only one of his company who became infested.

The prevailing view was that the Guinea worm, lying under the skin instead of in a cavity of the body, afforded conclusive proof of the origin of parasites within the host.

In 1870 Fedschenko first found that if the larvæ discharged by the parent worm escape into water they may be taken up by the little crustacean, *Cyclops* and within its body they develop to a certain stage. Man becomes infested by swallowing the Cyclops in drinking water. Since Fedschenko's announcement there has been abundant verification. We can only conclude that the Baron von Jacquin must have broken his pledge, for we have no evidence that Cyclops will thrive except in water.

Among the worms found to require an arthropod as intermediate host were several species of thorn-headed worms. In 1873 Leuckart showed that *Echinorhynchus proteus* and *Echinorhynchus angustatus* of fish develop as larvæ in two Crustaceans, respectively *Gammarus pulex* and *Asellus aquaticus*. One of this same group of worms which sometimes occurs in man was found by Grassi and Calandruccio, 1888, to develop in the meal infesting larva of Blaps. Still another, the largest of the group, develops in the larva of the June bug.

Other instances might be cited, but it is not my purpose to make this a mere catalogue of the parasites which were early

known to undergo a part of their development in insects. It is rather my desire to show that long before the amazing discoveries of the relation of mosquitoes to malaria, and the other contributions of the past twenty-five years, the foundation was being laid. Without that foundation the building could not have been erected. Would it not be interesting if today we could tell what stones are being rejected which may become the cornerstones of the future?

Above all, a review of the history of any theory emphasizes the fact that no man lives to himself alone, and that no honest effort to get at the truths of nature, no matter how insignificant they may seem, is without its value. The man who scorns scientific work which has not an obvious utilitarian trend is ignorant of the history of applied science. The scientific worker who tries to build about himself and his subject a wall of defense against impractical ideas or against what he regards as rival subjects, will merely succeed in insuring himself against recognition by his followers.

THE GENITALIA OF MALE SYRPHIDÆ: THEIR MORPHOLOGY, WITH ESPECIAL REFERENCE TO ITS TAXONOMIC SIGNIFICANCE.*†

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The Syrphidæ are a group of very handsome flies, variously known as hover flies, flower flies and sweat bees; and, indeed, most often passed by the layman as stinging wasps or bees.

There are perhaps 500 known species from North America and the individuals are very numerous so that it has been an attractive field for the systematist and there are many students of the group. A very excellent monograph of the family by Dr. S. W. Williston[10], written in 1886, has also been influential in attracting attention to this family.

Unhappily the impression has prevailed that these flies are easily classified; and many amateurs who would not have ventured to name a bug or a beetle or a mosquito, have created synonyms in this group after the most meager study.

Nor has the confusion been confined to the collections of amateurs. I was surprised to find in the collections of four of the best known specialists of this group in America, four distinct species under the name *Sphegina lobata*, and four different species named *Sphærophoria cylindrica*. On the other hand in a number of cases the members of a single species were passing under two or three different names in these collections; *e. g.*, *Pipiza femoralis*.

This is not a reflection upon the systematists, but it is a good indication that the characters we have been using for this family (so largely color markings) are insufficient or untrustworthy and misleading in many cases. The conviction seems to be general that the more trustworthy, taxonomic characters are the *structural* ones of shape or architecture, sculpturing or puncturation, and variations in the number, position, structure and proportions of the appendages.

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Of such structural features the latest to be discovered and generally adopted as of vast importance in the taxonomy of insects are those of the genitalia. When one considers the great number of characters, many of them intricate and trivial, that students have invoked for use in this family, one who has studied the genitalia cannot but marvel at the extent to which these characters have been neglected by even the most careful students.

Of course in those families of insects where the parts are, at least in part, normally exposed they could not be entirely neglected by systematists. But in the groups where their examination requires some preliminary preparation or manipulation, they have been most persistently ignored; and, indeed, the presence of any variable structures appears to have been altogether unsuspected. For example, for the Diptera, the only reference that Peytoureau[6] as late as 1895, gives to the genitalia of this enormous order is to the work of Dziedzicki and Wagner on certain genera of the Siphonaptera!

Many a writer has taxed his eyesight and racked his nerves trying to separate, by minute differences in color markings or vestiture, species that were provided with structural characters by which any novice could place them. The reason for it is that these parts are normally almost entirely concealed from view (See Figs. A to I, Plate IX), and require a little special preparation before they are available for use. One can almost fancy that Nature has indulged in a kind of practical joke in hiding these excellent structural features from the curious eye; for in the Syrphidæ the most beautifully variable appendages are often concealed beneath the most unpromising and discouragingly homely tergites of the postabdominal segments. (Note Figs. A to I and cf. Plates X to XIX). One can hardly restrain one's enthusiasm upon relaxing and exposing from the exactly similar genital pouches of species after species, a complex of appendages that show an abundance of characters and furnish much ground for speculation regarding homologies, phylogeny and relationships.

Since Peytoureau's time, much work has been done on the genitalia of the Diptera, most noteworthy of which is that of Howard, Dyar and Knab[3] on the Culicidæ, Johannsen[4] on the Mycetophilidæ and Snodgrass[7] on the Dolichopodidæ. Those

families are all ones in which little or no color differentiation is available for use. Hence, it has been particularly interesting in this family of large, brilliantly-marked flies to see how color markings would stand the acid test of comparison with really tangible structural features.

So far as the Syrphidæ are concerned, only scattered references to the genitalia are to be found. Verrall[8] observed that the parts are unsymmetrically twisted to the right and, in several cases (*e. g.*, *Sphærophoria* and *Tropidia*), he gave superficial drawings of the parts. Walter Wesché[9] makes frequent reference to the condition of the parts in the Syrphidæ and gives figures of three species. Berlese[1] has given an excellent figure of the genitalia of *Eristalis tenax*. J. Herve-Bazin, in his treatment of the Syrphidæ of the Congo[2], makes occasional reference to the exposed parts, but gives no description of the concealed parts. Lundbeck[5] gives especially valuable observations upon the condition of the segments of the postabdomen and remarks upon the appendages of certain species, but I feel sure that neither he nor Verrall had ever seen a cleared specimen and had little intimation of the valuable characters to be drawn from these parts.

SCOPE AND AIM.

In the present investigation the genitalia of only the male sex have been studied. The aim has been to determine the general character of the genitalia for this family, for the various genera, and for the several species; primarily as a help in limiting and clearly defining species and in fixing the limits of many of the genera now hopelessly intergrading and admittedly unsatisfactory. Furthermore, in these characters have been found some evidence regarding the phylogeny of the family and some good sub-family or tribe characters. The present paper is intended as an introduction to a series of taxonomic papers based on genitalic characters that are now prepared and in preparation and it is hoped also that it may serve as an introduction to this method of study for other specialists on this family. The writer must confess that his interest has been primarily taxonomic and that he has been least of all concerned in the much-mooted question of homologies and nomenclature of parts.

ACKNOWLEDGMENTS.

Nearly ten years ago, in a letter commenting upon my work with the biology of the Syrphidæ, Dr. Raymond C. Osburn, then of New York City, made the following suggestion:

"If you can secure the material, the study of the development of the genitalia in the pupa would be most interesting, as nothing has been done on that point in the Syrphidæ."

However, it seemed most expedient to determine first the actual condition of the parts in the adult before attempting the more difficult task of elucidating their embryonic development. Ever since that time I have had in mind an investigation of the hidden treasure of characteristics to be found in the male genitalia of these flies. Occasional specimens have been examined from time to time, but it was not until 1918-19 that an opportunity was afforded for a comprehensive study of the problem. The writer acknowledges with gratitude the early suggestion of the problem and also the interest shown in its solution and fruition by Doctor Osburn since he and the writer became associated in the same department.

A paper such as this, the value of which depends fundamentally on the correct identification of the materials used, and which requires a large series of specimens and species, is not possible without much aid and assistance from fellow workers. I feel that I have been unusually fortunate in this respect, for in almost every case the material desired has been given with the utmost generosity.

Much of the material studied is from my own collection. This has been supplemented in many cases by specimens from other collections and determined by other workers. In a number of cases I have been fortunate in securing type material. All of the important American genera and most of the minor ones have been studied, about sixty in all, represented by about two hundred species. To attempt a detailed statement of the materials loaned to me would require too much space; but I wish to express my gratitude for such aid to the following gentlemen:

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ILLUSTRATIONS.

The drawings have been made with several objects in mind: first of all, to exhibit the characteristic structures which may be used again and again by taxonomists in determining the species; but also to record the morphological structure of the parts, even those which are obscure, in order that homologies might be traced throughout this group and eventually with other families and even the other orders; and finally not without some joy in presenting the intricate and often artistically beautiful structures which Nature has here hidden from the cursory observer.

Hence, much more extensive drawings have been made than would be necessary to illustrate the points needed in taxonomy; the characteristic structures are not unduly emphasized in the figures, although they are pointed out in the text; and no uniform position, such as strictly dorsal or strictly lateral, has been regularly chosen for the views presented. The attempt has been made to place the parts in the position which would show the characteristic features to good advantage and also give, so far as possible, an *ensemble* of all the structures present. Most often this has been a ventral or cephalic view; although the lateral

aspect shows almost as many of the features. In a good many cases both views are presented. The drawings have been outlined with the aid of a camera lucida, the outlines then proved under the binocular and finally again examined under higher powers of the compound microscope as they were inked. The writer believes that the drawings given herewith, which show the parts all assembled, will make it easily possible for any taxonomic worker to use these characteristics in determining and defining species. When isolated appendages alone are figured, the tyro finds great difficulty in determining what part is represented and what view of it is figured.

METHODS OF WORK.

I am so much interested in seeing the general adoption of the genitalic characters as an aid in the characterization of species that I venture to describe, somewhat fully, the methods I have found useful in preparing these parts for study, in the hope that even the isolated worker, not accustomed to laboratory methods, may not hesitate to make use of the valuable characters to be found in the terminal appendages of these flies.

Every worker will, of course, develop his own particular methods of procedure, and there is little if anything new in the methods which I have used. But it will at least serve as a starting point, for it has enabled me to prepare hundreds of these parts without the loss of, and almost without damage to, a single one.

Three kinds of material will ordinarily fall to one's hands for use: freshly killed specimens, alcoholic ones and dried, pinned ones. All of them are valuable: indeed, for the chitinous parts with which the systematist is concerned, I believe the pinned specimens are as good as fresh ones, although the worker would do well to secure fresh material whenever possible as a check upon preserved material.

(1). In any case I always first pin the specimen and then attach to the pin a serial number which is also placed (together with the name of the insect and any other data) in a notebook. Personally I use the space provided in most slide boxes, putting the number and name of the insect opposite the space which will eventually receive the prepared slide of the genitalia.

(2). If the material is freshly killed, this step is to be omitted. With material which is set, however, the next step is to relax the insect by placing in a moist chamber or relaxing jar. The length of time required for this process will vary with the species, the degree of chitinization of the specimen and the length of time it has been killed. As a rough average, I have found about thirty-six hours to be

sufficient. A reliable test is to leave them in the moist jar until a wing or leg can be moved without breaking.

The relaxation can be accomplished almost instantly if necessary by applying boiling water in a small camel's-hair brush directly to the parts, or by plying a tiny jet of steam against the genitalia, or even by dropping the specimen briefly in boiling water. Owing to the greater injury to the colors and vestiture of the specimens likely to be caused by these methods, I prefer the moist chamber. For the same reason it is important to leave the specimens in the relaxing jar only so long as is necessary to accomplish the purpose.

(3). The fresh or relaxed and pinned specimen is then held ventral side up, by the left hand under the dissecting microscope, while with a fine needle the retracted genitalia are pried or drawn out of the cavity formed by the invagination of the terminal segments at the ventro-caudal extremity of the abdomen. I have found by removing the metal stage of the binocular and placing a microscope slide across to bisect the field of vision that the tip of the abdomen can be rested against the edge of the slide and the parts pried out most easily. Any elevated, sharp edge at the middle of the field so that the head of the pin is not in the way, will do as well. With properly relaxed specimens, and a little care, one can remove these genital segments and leave the rest of the specimen in almost perfect condition for cabinet purposes. Of course, if one does not care for the specimen, it will suffice to simply clip off the tip of the abdomen a little beyond the middle with a fine scissors. Or, indeed, the whole of specimens not needed for the cabinet may with great interest and profit be carried through the successive stages, thus revealing many features of the chitinous structure not readily made out from uncleared specimens.

Before severing the genital segments it is well to study the relations of the modified segments (postabdomen) to the unmodified segments (praeabdomen), noting any variation in number of segments involved or characteristics of length, shape, size and arrangement of these parts. It is also well at this point, to make an examination, descriptions and preliminary sketches of the separated, opaque parts, since in this condition certain features are better revealed than in the cleared preparation. Indeed if several specimens of the same species are available, it is advisable at this point to preserve one without clearing, using for the purpose small gelatine capsules which are securely sealed by closing and thrusting on to the pin bearing the insect itself. This also affords a precaution against being misled by any possible artifact due to subsequent treatment.

(4). A duplicate of the serial number (in carbon ink on a tiny slip of paper and thoroughly dried) is now placed, together with the detached genital segments, in a container for treating with caustic potash. For this purpose I use small shell vials or test tubes, about 8 x 70 mm., that have had a part of the bottom removed by means of a diamond point, or by heating the bottom in a gas jet and blowing out the molten glass. This bottom is then replaced by a plug of cotton. Sections of glass tubing may be used, but I prefer the vials, as the partial shelf of glass prevents the cotton plug from dropping out. With this arrangement the specimens can be passed rapidly through the remaining treatment without the necessity of once touching the parts themselves. It is only necessary to raise the vial until the liquid has drained out through the cotton bottom, rinse it with a few dropper-fulls of fresh liquid, and then place it in the next reagent, which will rise and promptly envelop the specimen.

By the use of these small containers it is convenient to carry through the subsequent operations a considerable number of specimens at a time without any danger of loosing them or separating the parts from their key numbers.

When the desired number of vials, each with its genitalia and serial number, (from a dozen, or less, to a hundred, as the case may be), have been prepared in this way, they are placed in a shallow dish with straight sides or cross partitions, to keep them upright; and into the dish is poured an aqueous solution of caustic potash, 10 to 15% strength, sufficient to bring the solution to a depth of a half inch or an inch in each vial. They are then allowed to remain in this condition, occasionally raising and lowering the vials to bring in a fresh supply of caustic, until the parts are almost transparent. The length of time required for this again

varies with the degree of chitinization, but I have found it takes much longer than usually estimated to reach a degree of clearness which gives the best results. In fact, after soaking the parts in cold potash for a day or so, I have usually boiled them for from three to six hours in the same solution. In this process the cotton-plugged vials are very useful; for if the cotton plug is made just tight enough it will not be raised by the boiling and this prevents the boiling over so often experienced with materials in a test tube. The shell vials in a small staining dish may be placed in a casserole; or a cluster of them, tied with cord to keep them upright, may be placed directly in the casserole. It is a wise precaution to use a shallow casserole, in which the tops of the vials will come above the edge, so that the contents will not be lost or mixed by the liquid in the enclosing dish boiling over into the vials, or vice versa.

(5). When the parts have been thoroughly cleared, the vials are lifted separately or collectively from the potash and placed in a second dish containing distilled water, and thoroughly washed. Two or three changes are sufficient, especially if the fresh liquid be added through the mouths of the vials, by means of a pipette.

(5a). If the specimens are large and not thoroughly cleared, they may now be improved by placing for some hours in glacial acetic acid. This dissolves any fat that may have escaped the action of the potash and also any crystals of potash that may have evaded the washing.

(5b). Again wash thoroughly in water.

At this point the worker has a choice of several methods successively described:

A.

The specimen can now be placed on a microscope slide with a few drops of water and a cover glass, for temporary examination. It can be kept indefinitely in splendid condition in a small vial of equal parts 95% alcohol, glycerine and water. If a permanent mount is desired, method B, C or D must be followed.

B.

If the slides are not to be transported, and can be protected from rough handling, a very satisfactory plan is to mount them simply in a drop or two of glycerine. This has the advantage of allowing one to move the specimen about very freely under the cover glass, to study it in all aspects. To make a really permanent mount, however, follow either method C or D.

C.

(6). The vials are transferred to a dish containing glycerine, for an hour or more. Proceed with step 10.

D.

(6). The vials are placed in a jar containing a stain made of one gram of acid fushsin and 25 cc. of 10% hydrochloric acid in 500 cc. water, for from ten to fifteen minutes. If the strength is reduced to half, the specimen can usually be safely left over night.

(7). Wash in water and

(8). Pass through several grades of alcohol, as 30%, 85%, 95%, two changes, and into absolute alcohol.

(9). Transfer a few at a time into xylol or carbol-xylol, so that no one remains longer than about a half hour, before you can arrange it on its slide.

(10). Prepare a microscope slide by scratching on it the number of the genitalia to be mounted, or by attaching a gummed label which may also bear the name of the insect, by whom determined and also locality and date if desired.

C.

(11). Place on the slide a drop of glycerine jelly, melted by gentle heat and

D.

(11). Place on the slide a drop of Canada balsam, dissolved in pure acetone and

with a brush or needle, quickly transfer the specimen to it. Under the microscope make sure the parts are spread to the best advantage and arrange them in the position desired.

C.

(12). Now quickly place the slide on a small piece of ice, if available, or allow to cool, in the meantime examining carefully to see that the parts remain in the desired position until the jelly has consolidated enough to hold it.

D.

(12). Maintain them in position until the rapid evaporation of the acetone leaves the balsam firm enough to hold it. If necessary to change the position, a little fresh acetone-balsam can be added as many times as necessary to soften the balsam. When firmly set and covered with balsam, the slide may be allowed to harden in a place free from dust for a day or so, or one may at once—

(13). Place around the specimen several pieces of a crushed glass slide, or glass beads, of a proper size to just keep the cover from crushing the mount, and then:

C.

(14). Add some more of the liquid jelly, and finally a cover glass. Chill thoroughly and set aside until wanted. When the specimen has been studied in this position, it can readily be changed by gently heating and manipulating under the cover glass with a fine needle.

D.

(14). Add a little fresh balsam and finally a cover glass. If it is necessary to change the position of the object, the cover must be removed by soaking the slide in xylol or acetone, rearranging and remounting.

While the above procedure may appear rather complicated, it may be noted that by a simple short cut, one may prepare a mount of the genitalia in a very short time, as follows:

Relax the specimen with hot water; boil the postabdomen in caustic potash solution until clear; and then mount in either a drop of water, in glycerine, or in glycerine jelly.

THE MALE GENITALIA.

By genitalia is meant the group of appendages at the caudal end of the abdomen, surrounding the genital and anal orifices* of male and female insects. Their dominant functions are the reproductive ones of mating, oviposition, etc., but they are also involved to some extent in defaecation and sensation.

These organs appear to consist primitively of four pairs of appendages (Newell[11]). The most prolonged and voluminous debate has ensued regarding the homology, and morphological composition of these appendages and the primitive numbers of the urites to which they belong. The evidence appears convincing that they are entirely homologous with the thoracic or ambulatory appendages. And, according to the concensus of opinion of morphologists, these four

*The term is more strictly limited to the genital appendages. In this family, however, the *cerci* are so intimately associated with the other appendages that they are, throughout this paper, treated as a part of the genitalia.

primitive pairs of appendages belong primarily to urites eight, nine, ten and eleven.

The most varied names have been applied, not only to the group of structures (genitalia, hypopygia, *genital apparats, l'armature genitale, armature copulatrix, geschlechtsanhange*, terminalia, pygidia, etc.), but also to each of the several parts. But in spite of the elaborate protest of almost every author who has dealt with these parts, at the confusion of names and lack of any knowledge of the homology of the various parts exhibited in the work of their predecessors; and in spite of several recent ambitious attempts to homologize the structures in all the orders of insects the problem remains today much as in the past. Each worker must select such names as are evidently appropriate for application to as many as possible of the structures that he finds; and, when this is done, must still devise names of his own for convenience of handling many other parts, the homology of which with other groups is absolutely unknown. The fact is that the variations of these parts in the orders of insects is so unlimited; and so relatively little detailed study of the conditions in various families has been completed; that the time is not ripe to attempt to construct an ancestral, hypothetical form from which the variations in the various groups can be derived, or even to say which of the parts in the groups described have had the same origin. Much as a more uniform nomenclature is to be desired, it seems to me that real, ultimate progress in this direction must await further isolated investigations, until we begin to comprehend something of the range of variation in the orders.

The posterior half of the abdomen of the males of the Syrphidæ has been completely transformed (See Figs. A to N, Plate IX) and curiously modified for the support, protection and manipulation of the genitalia proper. This has resulted in dividing the abdomen sharply into two groups of segments; a caudal portion that is reduced in size and modified in shape or position or both, until it is quite distinct from the normal urites of the cephalic portion. I have found it convenient to designate these two divisions *the preabdomen* and *the postabdomen.*

NUMBERING OF THE SEGMENTS.

The following assumptions, in line with the conclusions of morphologists, but still assumptions, I believe, have been made in interpreting the identity of the segments in the postabdomen.

(1) The anus opens primitively between the eleventh tergite and its corresponding sternite, though these sclerites may not be recognizable in the highly specialized insects.

(2) The genital orifice is primitively between the ninth and tenth sternites, though the development of the penis may carry it to a point without any evident relation to the tenth urite.

(3) There are never more than eight pairs of spiracles on the abdomen.

(4) In the Diptera the style-bearing segment is the tenth.

If these premises be sound, it is evident that a complete renumbering of the segments of the abdomen is called for.

There has been great discrepancy in the numbering of these segments by various taxonomic and morphological students. Lundbeck (*5*, p. 23), for example, considers that the ultimate, or style-bearing segment is the ninth; that the postabdomen has four segments if the preabdomen has five and the postabdomen five when there are but four not transformed; although the most cephalic of the postabdomen may be hidden. Like all taxonomic workers, he calls the first apparent urite next the thorax the first abdominal segment. Berlese (*1*, p. 327), in his treatment of *Eristalis tenax*, interprets the numbers of the segments very differently. The apparent first next the thorax is, according to this author, in all the Diptera, number three; and consequently the last of the preabdomen in *Eristalis* (number four of taxonomists) he calls the sixth. His interpretation of the postabdomen is also at variance. He considers that the style-bearing segment is number ten, which I think is correct. But there are clearly *four* sclerites between this one and his so-called sixth, as shown by his own figure, (*1*, Fig. 395, p. 327). This would make the style-bearing segment the eleventh, or else the last of the preabdomen would be five. This difficulty he obviates by calling the basal *two* sclerites of the postabdomen together tergite seven, explaining that "the seventh has a large basal expansion." In this, I am convinced Berlese is in error, as the condition in the various genera and species clearly shows. (Follow Figs. M. and N. of Plate IX). The short, wide, chitinous bow ("large basal expansion" of the seventh urite), sometimes retracted under the last sternite of the preabdomen, is a modified sternite, as shown by the position of the spiracles, and, if the style-bearing is in reality number ten, then at most only one (and not two urites, as Berlese claims) has been lost between the thorax and abdomen in this family. His "large basal expansion" of the seventh segment is in reality the sixth sternite. Lundbeck has had the truer understanding of the abdomen, his position being correct as to the *number* of segments present in the abdominal region (namely, nine); but probably not as to the correct *primitive numbers* of these segments. That is, he recognizes no lost or transformed urites at the base of the abdomen and consequently calls the style-bearing urite number nine instead of number ten.

The evidence appears to me conclusive enough to warrant taxonomists making a change in nomenclature to conform with the morphological evidence in this and other families. There are nine discernible urites cephalad of the anal segment (eleventh), the first urite apparently having fused with the thoracic mass. Therefore, the segment of the abdomen which has hitherto been called the first in all taxonomic writings, should be numbered *two;* the so-called second, *three;* three, *four*, etc. While this will seem radical to systematists, it is clear that a nomenclature founded on error cannot permanently endure and if the change must come, the sooner and more generally it is adopted the more rapid and stable our progress will be. In this paper, therefore, the writer has adopted this nomenclature for the abdominal segments.

PREABDOMEN: URITES TWO TO FIVE OR SIX.

I have made no attempt to study urite one, though I believe it may be found by a careful examination of the thoracic mass.

URITE TWO is generally small, usually much shorter and also narrower than the succeeding ones. It is overhung by the scutellum (Fig. A), and has in some systematic descriptions been entirely overlooked—urite three being called the "first" abdominal segment. In *Chilosia* spp., *Xylota*, etc., it is unusually large, sometimes nearly equaling the third segment in length.

URITES THREE, FOUR AND FIVE are generally subequal in size and the largest of the abdomen. Their tergites are typically considerably wider than long, convex dorsad, the convexity in the transverse direction greater than that in the longitudinal direction. In some genera and species however, as in *Baccha*, *Ocyptamus*, *Sphegina* and *Sphaerophoria*, all or a part of the tergites may be much longer than wide. The sternites are invariably narrower than the tergites and less convex, but of about equal length. Typically in a cross section the sternite would occupy the diameter of the half circle or ellipse made by the tergite. Between tergite and sternite the body wall is unchitinized and these portions of the urite, the *lateral conjunctivæ*, bear the spiracles. In certain genera the chitinized ventral sclerites (sternites) are much reduced in area and the lateral conjunctivæ become proportionately larger. This is particularly noticeable in *Helophilus*, *Tropidia*, *Sphegina* and *Syritta*.

SIXTH URITE. The transformation from pre-abdomen to post-abdomen comes in the region of urites five to seven and the sixth shows the greatest variation in its development from genus to genus. In a few cases the sixth urite terminates the preabdomen; that is, it is not transformed, or but slightly so, and one can recognize five segments in the preabdomen (Fig. K, Plate IX). The sixth is then always shorter than the preceding segments and generally somewhat narrower. Both tergite and sternite clearly belong to the preabdomen in the following genera: *Platychirus*, *Pyrophaena*, *Allograpta*, *Baccha* and *Mesogramma* (Figs. K, L, Plate IX). In these cases the sixth tergite is about equally developed and quite similar in position and appearance to the fifth tergite in some of the other genera, (cf. Terg. VI, Fig. K, with T5, Fig. A). It is frequently a little unsymmetrical, as in *Platychirus* for example, where it is shorter and more bent downward on the right side. In *Baccha* it is of considerable length and nearly as wide as, or sometimes actually wider than the preceding. The sixth sternite in these cases is shorter than its tergite, but it is of about equal length throughout its width and not modified except perhaps a little depressed toward its right side.

From such a condition one can follow a clear series of specializations as a result of which urite six becomes more and more transformed in adaptation to the distorted postabdomen. Since the postabdomen as a whole is the result of an adaptation to the accommodation and manipulation of the genital appendages, it is clear that the distortion has pro-

pressed cephalad and that the genera just decribed are more primitive in this respect than those which have the sixth urite variously transformed.

As urite six becomes more affected the sternite first becomes transformed while its tergite may retain practically its normal shape and position. In the genus *Syrphus* the sixth sternite is variable; in some species (e. g., *S. arcuatus*) it stands full width of the hind margin of the fifth sternite, only shortened toward the middle or right side (Fig. F, Plate IX); in other species it is confined in its chitinized portion more or less completely to the left half of the abdomen, when it may be more properly be called a part of the postabdomen. The latter condition is found also in *Chrysotoxum* (Fig. H, Plate IX) *Sphærophoria* (Fig. 1, Plate XV), *Paragus* and *Eupeodes* (Fig. 134, Plate XIX).

In *Sphærophoria* (Fig. 1, Plate XV) the sixth tergite is large, in the common species being roughly two-thirds as long as the fifth. It is unsymmetrical, the right hand corner being prolonged into a triangular or rounded lappet. This sclerite is also a little unsymmetrical in *Eupeodes*. The sixth sternite in *Eupeodes volucris* (Fig. 134, Plate XIX), is longest and reaching nearly to the apex of the sixth tergite on the left side but much shorter a little to the right of the middle line (f, Fig. 134), where it is depressed to form a cavity for the apex of the penis.

In *Melanostoma, Didea, Xanthogramma* and *Syrphus* some species show urite six entirely untransformed, others have the sternite confined to the left side and the tergite normal or nearly so; while still others reflect the next condition in which the tergite likewise becomes involved in the distortion. Thus in *Didea fasciata fuscipes* it is somewhat upturned at apex and broadly and shallowly emarginated on the caudal margin. In *Melanostoma mellinum, Syrphus ribesii*, et al. the sixth tergite is much shorter on the right side.

Finally there is a large series of genera in which urite six has become completely transformed into a part of the postabdomen. In these cases it is usually not visible from above in the unrelaxed specimens and urite five terminates the preabdomen (Figs. A, C, E, G, Plate IX). Generally the fifth tergite is of about the same size as tergite six of the genera described above. Thus the preabdomen consists of only four discernible segments (Fig. A, Plate IX). This is the case in the following genera: *Psilota, Cnemodon, Chrysogaster, Sphegina, Rhingia, Hammerschimidtia, Volucella, Copestylum, Eristalis, Helophilus, Mallota, Sericomyia, Condidea, Arctophila, Pyritis, Tropidia, Teuchocnemis, Triodonta, Pterallastes, Syritta, Xylota, Calliprobola, Brachypalpus, Myiolepta, Criorhina s. s., Blera, Somula, Crioprora, Milesia, Callicera, Spilomyia, Meromacrus, Ceriodes, Temnostoma, Microdon, Mixogaster.* The fifth tergite is unusually elongate in *Myiolepta* and *Microdon*. It is unsymmetrical in *Criorhina*. A part of the postabdomen is almost always visible caudad of tergite five (usually urite nine and more or less of the adjoining sclerites) (Figs. A. C, E, G, I, Plate IX), and this has in some systematic papers been designated "segment five" or the hypopygium.

In the genus *Chilosia* (Figs. A and B, Plate IX) there are only four distinct segments in the preabdomen (urites two to five inclusive) but

retracted underneath the fifth is a very short sixth of nearly equal width; and projecting slightly from under the fifth tergite on its left side, are two very small unsymmetrical tergites (seven and eight) that narrow rapidly toward the right side where they become entirely concealed by the fifth tergite. In some species tergite six is also normally slightly exposed at the extreme left (Fig. A, Plate IX).

THE GENITAL POUCH. As indicated above it is chiefly the adaptations to the large genital appendages, when at rest, that are responsible for the transformation of the basal segments of the postabdomen—especially urites six, seven and eight. The same stimulus has resulted in a depression near the apex of the venter of the preabdomen, into which the penis, styles, etc., are received when not in use. This depression I have called *the genital pouch.* (Figs. 95, Plate XVI; 134, Plate XIX; 73, 69, 77, Plate XIV). It is developed to the most variable degree, showing a high correlation with the size of the postabdominal appendages. Its beginnings are shown in the cases already described (Fig. F, Plate IX) in which sternite six is first depressed toward its right side then looses its chitinization in this region.

However, in cases where the genitalia are larger, the terminal segment of the preabdomen, namely tergite five and sternite five, (Figs 69, Plate XIV; 95, Plate XVI), gape apart toward their apex and the transverse conjunctivæ become actually introverted beneath sternite five carrying with them to a variable degree urites six and seven.

Correlated with this movement we find a further tendency to modify especially sternite five to aid in grasping the female abdomen. In *Helophilus* the fifth sternite is strongly drooping and has the caudal margin emarginated and sometimes sharply keeled at the middle, but symmetrical. In *Teuchocnemis* and *Triodonta* the caudal margin of the fifth sternite is much thinned, looking something like a short broad additional sternite fused to it. In *Syritta pipiens* there is a strong, V-shaped emargination of the caudal margin that reduces the median length of the sternite to about half that on the sides. In *Somula decora* the fifth sternite has a short rectangular prolongation of its caudal margin covering the middle fourth. In *Ceriodes tridens* there is a sharp median keel narrowing cephalad. In *Mallota* there is a fringe of long hairs a short distance removed from the caudal margin of the fifth sternite.

The genus *Sphegina* shows some interesting modifications of the fifth sternite. In *S. infuscata* this sclerite is hardly at all specialized either in shape or in vestiture, being only a little longer on the left side. In *S. clunipes* there is a narrow, shallow emargination of the caudal margin near the middle and about this emargination are many, much elongated, but not at all stout hairs, not divided into two groups. In *S. rufiventris* (Fig. 77, Plate XIV) there is a shallow, rounded emargination of the caudal margin near the middle (d) and this is bordered with several dozen very heavy short hairs tending to divide into a right and left group. At each side of these spiny hairs the vestiture is three or four times as long and more delicate. In *S. petiolata* (Fig. 73, Plate

XIV) the distal emargination is unsymmetrical and about this emargination the hairs are elongated and thickened, but not sharply distinct from the others on this sclerite. Projecting strongly from under the left side of the fifth sternite and between it and the sixth sternite the transverse conjunctiva on the left side forms a large blunt somewhat chitinized lobe (o, Fig. 73, Plate XIV,). The ventral body wall is then strongly introverted so that the sixth sternite is entirely hidden underneath this lobe, forms the ventral floor of the genital pouch and lies with its venter directed dorsad. In *Sphegina lobata* (Fig. 69, Plate XIV) we have a very similar condition except that in this case the ventral wall of the projecting lobe is covered by a strong protuberance of the left side of sternite five instead of being made up wholly of the transverse conjunctiva. The vestiture about the strong unsymmetrical caudal emargination of the fifth sternite is short and stiff. There is a similar, though not so prominent projection of the left side of the fifth sternite in another species of *Sphegina*, and the genital pouch is still more strongly developed (Fig. 78, Plate XIV). In *S. campanulata* the genital pouch is also very large.

The way in which the development of the genital pouch has influenced these remarkable emarginations of the caudal margin of sternite five is indicated in an unnamed *Sphegina*, where the genital pouch is but slightly introverted but the part of the fifth sternite directly underlying and adjoining it (in a large U-shaped area reaching three-fourths the way to the base of the sternite) is exceedingly thinly chitinized and but one step removed from a very strong emargination of this sclerite. In *S. latifrons* the fifth sternite is quite symmetrical and unusually long, though its apex hardly reaches the caudal third of its tergite. On the basal third is a median swelling bearing about a dozen spinose hairs on each side. Between this and the apex the segment is transversely concave and the distal margin is bituberculate—the tubercles as far from each other as from the lateral margin, each semi-globular and with a dense tuft of hairs, much as in *Tropidia quadrata* (see below). Of these hairs, some are similar to those on the median tubercle, but many are four times as long and stiff. These tufts when the parts are at rest, guard the apices of the elongate styles. The genital pouch is but feebly developed, its place being taken in part by the tubercles.

A condition remarkably similar to that in *S. latifrons* is found in our common *Tropidia quadrata* (Fig. 95, Plate XVI). The fifth sternite has a median caudal emargination, guarded by two very densely hairy tubercles that help to complete the genital pouch formed by the introversion of the sixth sternite and the transverse conjunctivæ bordering it.

In *Eumerus strigatus* the caudal margin of the fifth sternite is produced into two large sub-quadrangular plates separated only by a linear incision on the middle line.

THE POSTABDOMEN: URITES SIX OR SEVEN TO ELEVEN.

Previous writers appear to have completely misinterpreted the condition of the postabdominal segments in these males. Berlese, in particular, has, for some reason that I cannot understand, in his Gli Insetti (*1*, Fig. 395, A, B, p. 327) mistaken the tergites of the postabdomen for the sternites and vice versa.

The only reasons I can see for this are (a) the *superficial resemblance* of the prominent sclerites in this region to tergites of the preabdomen and (b) *their similarity in position* to the style-bearing, tenth, tergite. The position of the appendages (styles) of this tenth urite appear to prove that the heavily chitinized convex sclerite marked Terg. X, (Figs. D, L, N, Plate IX) is the tergite; and by analogy one might easily assume that the preceding sclerites of similar appearance (Urite IX, Stern. VIII, Stern. VII, Figs D, L, N, Plate IX) are the preceding tergites. This Berlese appears to have done. Such assumption would presuppose a most remarkable twisting of the abdomen on its long axis between preabdomen and postabdomen. Berlese assumes that this twisting has been counter-clockwise, so that the mid-dorsal line of the sclerites that he calls *tergites seven and eight*, lies at the left side. As a matter of fact, as I shall show, the flexure has been in the opposite direction (clockwise); and what Berlese calls tergites seven and eight are sternites, while his sternites seven, eight and nine are the tergites, not of seven, eight and nine, but of six, seven and eight.

The evidence for this is perfectly conclusive. The most important landmarks for determining homologies in this region are the spiracles and the longitudinal tracheal trunks. In fact, in certain species one can follow the lateral conjunctivæ between the preabdominal and postabdominal segments; and it is perfectly evident that the sclerite marked Stern. VI (Fig. N, Plate IX) is homologous with that marked Stern. V, and so with those marked Stern. VII and Stern VIII. Likewise in Figure M, the sclerites marked Terg. VI, VII and VIII are unquestionably homologous with that marked Terg. V. More conclusive evidence is the course of the tracheal trunks which, as shown in Figures 69A and 69B, Plate XIV, have no twisting or crossing over. By following the latter it is perfectly evident that no such remarkable flexure as that demanded by Berlese's interpretation has taken place. (follow Figures 69A and 69B, Plate XIV). The left tracheal trunk passes directly back to the spiracles 6, 7 and 8; the right one bends to the left and passes as directly as may be to the right spiracles 6, 7 and 8.

The peculiar condition of the terminal urites (postabdomen) in this family will be best understood if we consider the changes that must have taken place in their development from the primitive condition of the abdomen. *First*, the caudal part of the abdomen must have become bent underneath, so that the sternites of the last few segments are in apposition to those immediately preceding (Figs. D, K, L, Plate IX). Following this, another important flexure has taken place as a result of which the segments after number seven are, *secondly*, successively displaced toward the right, curling about in a semicircle from left

to right (Figs. B, D, F, H, and L, Plate IX). This has resulted, *thirdly*, in crowding the basal segments of the postabdomen (urites six, seven and eight) more or less completely over to the left side of the apex of the preabdomen (Figs. D, L) to accommodate the enlarged tip of the abdomen. Accompanying this bending under and curling around toward the right, has occurred *fourthly*, a rotation clockwise on the long axis (Figs. M, N) usually for about one-fourth of a revolution on the seventh urite and progressively more on the eighth and ninth. As a result of the above modifications, we find in the present-day species that the apex of the postabdomen points cephalad instead of caudad, (Figs. B, D, F, H, K, L) and that the *mid-dorsal* line of the tenth urite (its tergum) lies near the *mid-ventral* line of the preabdomen and its sternite lies practically dorsad of its tergite. *In the fifth place*, in many genera, the terminal tergite and sternite of the preabdomen have gaped apart at their apex (Figs. 69, 73, Plate XIV; Fig. 95, Plate XVI), and, *sixthly*, the transverse conjunctivæ bordering the sixth sternite have often become introverted between these two sclerites to form a sort of genital pouch, often carrying inward also one or two of the basal segments of the postabdomen. When at rest then the apices of the appendages borne by urites nine and ten often lie in such a pouch sometimes to their very bases (Figs. B, D, F, Plate IX).

URITE SIX IN THE POSTABDOMEN. In the completed condition, then. (Figs. B, D, H), urite six, when not a part of the preabdomen (see above) is often found as a very short and narrow sclerite, underneath the left side of the fifth tergite; or it may be nearly as broad as the fifth sternite, but mostly or entirely hidden under this sternite.

URITES SEVEN AND EIGHT are small, short, and more or less strictly confined to the left side; the former wholly, in part or not at all received into the genital pouch; the latter wholly, in part of not at all projecting beyond the last tergite of the preabdomen in dorsal view (Figs. A, C, I). They are twisted clockwise on their long axis, so that their mid-dorsal line points almost directly dextrad (Fig. M) and their mid-ventral line nearly directly senestrad (Fig. N).

In contrast with the condition in the preabdomen, the sternites of the postabdomen are more heavily chitinized and more convex and often of greater actual area than the tergites. Generally, however, the area of the tergites is greater than at first appears, because they are so greatly distorted and folded upon themselves. The only way in which boundaries can be clearly recognized is to follow the lateral conjunctivæ and particularly note the spiracles. The lateral conjunctiva of the right side (Fig. M) lies just dorsad of the right margin of sternites six to eight. When the parts are extended, it therefore bends sharply to the left and ventrad (Figs. L, M) after the last segment of the preabdomen (five or six) and beyond this point its course describes part of a circle or ellipse with the concavity toward the right.* In the retracted

*A condition which may have a great deal of significance, but which I am not able to interpret at present is shown in a specimen of *Eristalis arbustorum*. In this specimen the right lateral conjunctiva appears to continue directly into what we have called the mid-dorsal line of the tenth tergite.

position of the postabdomen the right lateral conjunctiva often makes a loop cephalad under the terminal sternite of preabdomen, following the segments introverted into the genital pouch. The right spiracle of urite six, when this segment is transformed into postabdomen retains its nearly normal position near the caudo-lateral corner of the preceding untransformed segment (Figs. L, M); that of urite seven may lie near the right side of the preabdomen or, together with the eighth, may be displaced far ventrad and often senestrad (Fig. L) to well beyond the mid-ventral line of the preabdomen.

The lateral conjunctiva of the left side is much less distorted (Fig. N). It bends dorsad and slightly toward the right beyond the apex of the preabdomen, following the spiral twist of this part of the abdomen. The left spiracle of urite six usually lies very close to the caudo-senestral corner of the fifth sternite, though it may be withdrawn underneath (dorsad of) the latter into the genital pouch. The left spiracles of urites seven and eight are displaced dorsad and also often caudad to near mid-length of their respective segments (Figs. K, L). They are not much displaced toward the right, so that *both* spiracles of urites seven and eight often lie to the left of the mid-ventral line of the preabdomen.

The true relationship of the sclerites in the postabdomen is much obscured in many genera by three specializations. (1) The left lateral conjunctiva has practically disappeared in some cases by the fusion of sternites seven and eight to tergites seven and eight respectively, on their left side (Fig. K); thus making practically a single sclerite of each of these segments with an evident break only at the right conjunctiva. However the spiracles clearly remain on the left side to show the homologies. In *Mesogramma geminata* for example (Fig. K, Plate IX), the break between sternite seven and tergite seven on the left side is indicated only by a slight change in density of chitin and a trace of a suture in front and behind, while on the eighth urite all that remains of the lateral conjunctiva is a trace of the suture over the cephalic half leading back to the spiracle.

(2) The second obscuring tendency is toward the disappearance of the tergites of six, seven and eight or rather, their dechitinization. It is as though the pressure from the genital appendages prevented in some way the laying down of chitin in those parts of the segments that line the genital pouch.

The tergites of six, seven and eight are very well chitinized in at least a part of the species of the following genera: *Chilosia, Mesogramma. Sphegina, Baccha, Milesia, Hammerschmidtia, Brachyopa.* and *Microdon.*

These tergites are moderately to feebly chitinized in the following genera: *Pipiza s. l., Chrysogaster, Syrphus, Catabomba, Didea, Chrysotoxum, Melanostoma, Pyrophaena, Sphegina, Baccha, Rhingia, Eristalis, Helophilus, Tropidia, Xylota, Calliprobola, Eumerus, Syritta, Sericomyia, Condidea, Spilomyia, Teuchocnemis, Triodonta, Somula, Criorhina, Blera, Crioprora, Mallota, Merodon, Temnostoma, Ceriodes, Volucella, Copestylum, Mixogaster.*

In the following genera the tergites of the sixth, seventh and eighth urites are apparently not at all chitinized, the area occupied by these sclerites being thin and membranous: *Paragus*, *Syrphus (pars)*, *Xanthogramma*, *Sphærophoria*, *Allograpta*, *Eupeodes*, *Platychirus*.

(3) The third specialization of the postabdomen that tends to make interpretation difficult is the tendency for certain segments to fuse. The fusion of segment eight with nine is shown in the genus *Paragus*. In this genus there are five tergites in the preabdomen while the sternite of five has been transformed. In *P. tibialis* the postabdomen shows five distinct segments of which three (6, 7 and 8) are small, confined to the left side, and subequal. In all the other species examined, however, one can find only four segments in the postabdomen, there being only two small subequal urites on the left side between the fourth sternite and the large penultimate segment (nine). However when one clears the specimens and examines this ninth segment carefully an obscure suture becomes evident which is undoutbedly a line of fusion between segments eight and nine. The cephalic portion so marked off is of the right size and shape for the eighth segment and the caudal portion of this compound segment about equals in size segment nine of *tibialis*.

Another example of the fusion of segment eight to nine is furnished by the species, *Eupeodes volucris*. (Fig. 134, Plate XIX). In this species a triangular eighth segment is fused to the left basal corner of the enormous ninth. The suture in this case is distinct toward the lateral margin but has wholly disappeared toward the median line.

Urite Nine appears to consist of a single sclerite; and in the absence of any spiracles on this segment it is a little puzzling to know whether it is sternite or tergite. Its relation to sternites eight and seven (Figs. B, D, K, L, N) makes it seem almost certainly a *sternite;* while the interpretation we have made of the tenth urite (calling the larger more convex sclerite the tergite) and the position of the penis (which we consider the appendage of urite nine) makes it seem equally certain that it is the *tergite* of nine that is represented. Most likely it is a fusion of both sclerites, completing the tendency cited above for these sclerites to fuse on the left side. In the absence of proof on this point we shall call the sclerite *urite nine*. This urite may extend farther basad on the right (Figs. A, B) or on the left or about equally on both (Figs. E, G, F, H), depending on the relative size of segments eight and ten. It is almost always larger than the preceding segments of the postabdomen and very frequently also much larger than the succeeding ones. It is very convex, the entire convexity forming about half a spheroid against the median diameter of which rests the base of the penis (Fig. O).

In the description of the segments of the postabdomen and of their appendages the peculiar flexure is of course kept in mind and the cardinal directions, aspects and margins are described *as they would appear if the abdomen were in the normal position.*

Tergite Ten. Urite ten is the most highly developed of the post-abdomen; and, in some of the genera (notably *Cnemodon* and *Pipiza*, (Figs. 17, 19, 23, Plate XI), it is the largest. Both tergite and sternite become very highly specialized. The tergite (see Figs. O, D, L, Plate IX) bears, towards its disto-lateral corners a pair of appendages, the styles, while its baso-lateral corners are a little, to much, produced ventrad and articulate to the sides of the basal rim of the penis (Figs. O, Plate IX; 6, Plate X; 34, Plate XII; 49, Plate XIII; and 76, Plate XIV). Its shape varies greatly, but is typically somewhat quadrangular in dorsal outline (Fig. 17, Plate XI; 69, Plate XIV), strongly convex dorsad and the sides flexed ventrad especially toward the base.

Its shape is much modified by the condition of the cerci or appendages of the eleventh urite, which are sunken into its distal margin to the most variable extent, sometimes almost imperceptibly so (Figs. 36, 38, 42, Plate X; 91, 95, Plate XVI; 133, Plate XIX; 109, Plate XVII), often about for half their length (Figs. 17, Plate XI; 2, Plate XV; 69 Plate XIV), in many other genera fully received (Fig. 55, Plate XIII), their apices just about reaching the apex of this segment. In *Pipiza* and its allies (Figs 20, 23, 25, Plate XI; 35, Plate XII) the tenth tergite is relatively very long and the cerci lie somewhat beyond mid-length, while its much produced lateral arms extend far beyond them. In *Sphærophoria* (Figs. 1, 60, 63, Plate XV), the climax is seen; for the lateral arms have, in some species, entirely fused beyond the cerci so that the latter lie in the middle of the large hemispherical enveloping tergite. See below under cercal emargination.

The Tenth Sternite (Fig. O, Plate IX), has taken on peculiar modifications of function and structure. The caudal part of the basal rim of the penis articulates to it along its basal margin; while distad it articulates to the mesal face of the styles. It thus comes to serve in many genera as a lever between the powerful clasping organs (styles) at its apex and the rigid penis rim at its base. (Figs. 14, 18, 19, 20, 23, 25, Plate XI; 34, Plate XII). This has originated a strong tendency for the sclerite to divide on the middle line from apex more or less completely to its base, as, for example, in *Cnemodon*, *Pipiza*, *Psilota*, *Milesia*, etc., (Figs. 14, 25, Plate XI; 35, Plate XII; 119, Plate XVIII); and in a number of species it is completely modified into a pair of rod-like, heavily chitinized levers, between which is only a thinly chitinized membrane. In *Microdon tristis* (Fig. 129, Plate XIX) the median margins of these two rami are bent ventrad at right angles to stand upright, closely parallel to each other. In *Volucella* spp. it is produced into a curious erect finger-like projection near the point of articulation to the penis rim. It also enters into an elaboration with the mesal face of the style in several cases; for example, in *Blera badia*, to form a sharp thorn, and in *Eumerus* a rounded, hairy elevation, both directed toward the penis.

The Eleventh Urite is for the most part represented only by its appendages, the cerci. However, in *Pipiza* and *Cnemodon* we find minute, chitinous sclerites, basad of these appendages, which

may be the remnants of the tergite (Figs. 20, Plate XI; 35, Plate XII). In *Mesogramma* a transverse, triangular sclerite closing the cercal emargination (Fig. 43, Plate XIII) and in *Mixogaster* (Fig. 133, Plate XIX) a similar transverse piece I have interpreted as the eleventh sternite. In a good many other species there is a small hairy region, ventrad of the cerci, which I interpret as the remnant of the eleventh sternite (Figs. 122 and 127, Plate XVII; 31, Plate XII). And then there are the remarkable cases of *Cnemodon* and *Sphærophoria*. In these genera there are rather prominent processes (the sternal cornua and the post-anal hood) caudad of the cerci, which are continuous with the distal margin of sternite ten and which are possibly the much modified sternite of the eleventh urite.

The most reduced condition of the eleventh sternite (if indeed these structures be the eleventh sternite) that I have found is in the species *Sphærophoria novæangliæ*. In this species the tenth sternite is emarginate distad and in this emargination stands a small, quadrangular, almost hour-glass shaped plate, placed transversely and with a basal arm to each side of the tenth sternite. It is not produced beyond the base of the styles although very slightly beyond the tenth tergite and tends to close in the floor of the cercal emargination beyond the cerci. It is thus only a little displaced from relation to its tergite which, when present, subtends the cerci.

In *S. cylindrica, scripta, menthastri*, etc., with the fusion of the arms of the tenth tergite along the middle line closing the cercal emargination (*vide infra*) we believe that this eleventh sternite has become pushed distad and produced into two separate processes standing mesad of the styles. These are the processes referred to as sternal cornua (Figs. 1, 65, 66, Plate XV). They are outstanding, variously-pointed, compressed plates, the mesal walls of which are continuous at their bases with the tenth sternite while their lateral walls continue into the mesal faces of the styles.

In the genus *Pipiza* we find a structure that is unique among the sixty genera that I have studied and that may represent a greatly elaborated eleventh sternite. I have called it the post-anal hood. It consists of a prominent, thin, membranous expansion between the styles, with which it articulates at their bases, and it is also continuous basad with the tenth sternite. (See figures 12 to 26, Plate XI).

It is my belief that this simple plate of *S. novæangliæ*, the sternal cornua of *Sphærophoria* spp., and the post-anal hood of *Pipiza* spp. are homologous structures and they may represent the eleventh sternite.

THE CERCAL EMARGINATION. In the process of compacting the segments of the postabdomen into a more or less globose mass, the eleventh segment and its appendages (the cerci) have been received to a varying degree into the apex of the tenth tergite. This is made possible by the emargination of the caudal margin of this tergite and this emargination is called *the cercal emargination*. It varies extensively and affords many good generic characters. It is very deep and large in many of the Syrphinæ (Figs. 6, Plate X; 31, Plate XII; 51, 55, 57, 58, 59, Plate

XIII), often reaching nearly to the base of the tergite on the middle line. In *Pipiza* (Figs. 17, 23, 26, Plate XI) and *Sphærophoria* (Figs. 1, 60, 63, 68, Plate XV) it is remarkably deep and in some species of *Sphærophoria* it has completely closed caudad of the cerci so that the latter are embedded in tergite ten. In the *Milesinæ* and *Eristalinæ* it is relatively slight, but has the margin often somewhat elevated, rim-like (Figs. 90, 95, Plate XVI). In some genera (e. g., *Chrysogaster*, Figs. 36, 42, Plate X), it is practically undeveloped.

THE CERCI (acrocerci, Berlese; appendage iv, Newell; lamellæ, Lundbeck; epiproct, Crampton; forceps superiores. Wesche) are the simplest and least variable of the appendages. They are typically one-segmented, sessile, semi-oval, compressed and lie closely parallel at either side of the anal opening. They are covered with minute microtrichia and also scattered, longer hairs, usually arising from rather prominent basal rings and doubtless tactile or otherwise sensory in function. Since they are so closely incorporated into the structure of the tenth tergite, it has seemed best to describe their directions and margins like those of this sclerite. Their length, therefore, is the distance parallel to the mid-longitudinal line of the tenth tergite and their width the transverse distance perpendicular to this. In cases where they become elevated and protruding, their heighth is the maximum distance more or less perpendicular to the plane of the tenth tergite.

A part of the species of the genus *Chrysogaster* shows a peculiarity of the cerci not noted elsewhere in the entire family for they are sometimes (for example, *C. pulchella*), distinctly two-segmented. (Note Fig. 36, Plate X). In the other species they are one-segmented; but in several of them (for example, *C. pictipennis*), very distinctly emarginated about the middle. So that it is possible, in this genus alone, to arrange a series in which the cerci show a very gradual transition from the one-segmented, not emarginated condition, through various degrees of emargination to the distinctly two-segmented condition. If we consider this a stage in the specialization, by fusion, from an earlier multisegmented condition, it places this genus as the most primitive of the family in this respect. But if we assume that the cerci in this group have, after an ancestral reduction to a single segment, again become divided, due to the emarginating tendency (noted also in other genera) it falls in line with the otherwise much specialized condition of the genus.

In correlation with the slighter development of the cercal emargination in some genera is the greater elevation of the cerci, either on their more basal end or on a slightly chitinized, bare, membranous petiole. In *Eristalis*, *Tropidia*, *Syritta*, *Ceriodes* and especially *Xylota*, they become very prominent relatively to the styles (see Figs. 91, 95, Plate XVI; 106, 110, Plate XVII; and 129, 131 and 132, Plate XIX), and the hairs, especially toward the apex, are larger and bristle-like. In *Microdon* they stand erect on a slender base, expanded, somewhat bilobed at apex. They are unusually poorly developed in *Brachyopa notata*.

STYLES (mesostyli, Berlese; appendage I, Newell; claws, Lundbeck; forceps inferiores, Wesche). The largest paired appendages of the postabdomen, with rare exceptions, are the styles. They are the appendages of the tenth segment (Fig. O, Plate IX), and stand more or less parallel to each other at the caudo-lateral corners of this segment. They articulate at base, typically broadly, to the tergite on the caudo-lateral margin and to the sternite on the cephalo-mesal margin; often the points of articulation are much restricted by emarginations of the tergite or the attenuation of the arms of the sternite.

The shape of the styles varies endlessly in the different genera and species. They usually afford a generic character and also frequently valuable specific characters. Typically they are erect, somewhat compressed and more or less adapted to clasp together, forceps-like. Such a simple condition is found in species of *Chrysotoxum* (Fig. 59, Plate XIII), *Syrphus* (Figs. 55, 56, Plate XIII), and *Mesogramma* (Figs. 43, 46, Plate XIII). Even in the most primitive that I find, there is a strong tendency toward the excavation of the mesal face, while the lateral surface is generally convex. From this medium condition there are several lines of departure. In one of them the style is progressively longer and more nearly cylindrical. Note *Paragus quadrifasciatus* (Figs. 9 and 10, Plate X), species of *Pipiza* (Figs. 12, to 26, Plate XI), *Chilosia* (Figs. 27 to 29, Plate XII), *Chrysogaster* (Figs. 36 to 41, Plate X), *Sphegina* (Figs 73, 74, Plate XIV), *Syritta* and *Eupeodes* (Fig. 134, Plate XIX). Almost invariably accompanying this elongation is a greater distortion evidenced by sharp curving mesad at apex (Figs. 12, 14, 17, 20, 21, Plate XI; 50, Plate XIII; 73, Plate XIV; 108, Plate XVII; 133, Plate XIX); by a curve near the base (Fig. 18, Plate XI; 40, 42, Plate X; 72, Plate XIV); or by curious bends and twistings somewhere about mid-length (Note Figures 2, Plate XV; 41, Plate X; 71, 79, Plate XIV, and 134, Plate XIX). The vestiture is almost always longer on the lateral surface and very often short and stiff or peg-like on the surfaces which are brought to contact when clasping, i. e., usually toward the apex on the mesal face. The apex also frequently becomes capitate, or serrate, or spurred or claw-like (Note Figures 24, Plate XI; 36, Plate X; 69, Plate XIV; 108, 109, Plate XVII; 134, Plate XIX).

A second line of departure from the typical, erect, compressed style is toward a greater broadening out cephalo-caudad to make an erect, short, thin style very wide cephalo-caudad. This is particularly characteristic of the genus *Sphaerophoria*, (Note Figures 1, 60, 66, Plate XV).

A third line of specialization is shown by many genera in the tendency to become forked or biramous or to develop an accessory lobe in addition to the principal one. This takes many forms and may be associated with either of the above types of style, i. e., with a long slender or a short broad one. This bilobed condition is very pronounced in *Sphaerophoria* spp., in which the lobes may be about equal in size (Fig. 66, Plate XV) or the caudal one much larger (Figs. 63 and 64) or the cephalic one larger (Fig. 60). Small lobes of various kinds

and situations are found among the species of *Pipiza* (Note Figures 12, 16, 17, 20, Plate XI; Fig. 35, Plate XII) and *Sphegina* (Figs. 69, 70, 79, Plate XIV) in which species it is usually caudad of the principal ramus.

In spite of the numerous variations there is one general type so predominant that it would seem to have some value as indicating relationships. I refer to the style that shows a massive, erect, more or less pointed or attenuated ramus and from its base on the cephalic side a more or less compressed, orbicular lobe that guards the penis at either side and that very often is densely spinose on its mesal face. The general type and also something of the endless variations will be evident from a study of Figures 4, Plate XV; 83, 84, 88, 89, 92, Plate XVI; 102, 103, 105, 106, 107, 122 and 127, Plate XVII; 115, 116, 118, 120, Plate XVIII; and 129, Plate XIX. It is almost the predominant condition among Williston's groups *Eristalinæ* and *Milesinæ*, and almost entirely wanting among the *Syrphinæ*. Sometimes this cephalic lobe nearly equals or even exceeds in size the caudal lobe as in Figures 94, Plate XVI; 110, 126, Plate XVII, and 132, Plate XIX. Either one of the lobes may bear teeth or hooks or be otherwise modified away from the general type as in Figures 87, Plate XVI; 100, Plate XIX; 124, Plate XVII.

Finally in regard to the styles we may note certain very characteristic types for some of the genera so characteristic that I consider them of value in defining the limits of the genus. In *Sphaerophoria* (Figs. 1 and 60 to 66, Plate XV) there are short, very broad, much compressed styles, convex laterad, with a more or less rounded, very hairy caudal lobe and a more angular cephalic one, often with one or two spurs or sharp angles on the mesal face In *Pipiza* (Plate XI, Figs. 12 to 26) there are erect, slightly compressed, forceps-like styles, bowing outward, curving, with an expansion usually toward the caudal side at base, slenderest about the middle with the apex expanded and typically provided with short, stout, peg-like hairs, about the point of contact with the one of the opposite side. In *Chilosia* (Figs. 27 to 29, Plate XII) we find an erect, almost straight style of varying length with sharp meso-caudal and meso-cephalic margins, the mesal surface between them slightly concave and with short spiny hairs toward its apex. Very often on the lateral face toward the caudal side there is a ridge or keel, in the more typical species highest basad and usually bearing long hairs.

In *Mesogramma* (Figs. L, Plate IX; 45, 46, Plate XIII) we note a thin, broad, flat somewhat quadrangular style, little specialized. The styles, alone, of the genus *Platychirus* will characterize the genus. They are bicornuate, the caudal horn from half as long as to of equal length with the cephalic horn; both compressed and convex laterad, and looking very much like the thumb and forefinger of one's partly opened hand.

In the genus *Sericomyia* (Figs. 108, 109, Plate XVII) we find a condition so peculiar and characteristic that on this basis one would feel justified in submerging the weakly characterized *Condidea*, since it has exactly similar styles. The styles are unsymmetrical (see discussion

under this heading below). The right one is elongate, gradually attenuated and bent mesad in a long sharp claw. The left style terminates in a blunt rounded process, the base of which is encircled by an elevated keel, something like a single turn of the thread ridge on a screw.

The styles in *Tropidia* (Figs. 91, 92, 93, Plate XVI) are not only bilobed as in many of the *Eristalinæ* and *Milesinæ*, but the caudal, erect lobe has further developed a third lobe between the other two. The first one next the cerci is erect, thick and more or less clavate the median one or baso-cephalic portion of the first (Figs. 91, 92, *a*) is strongly compressed, concave mesad, on which face it bears dense, short, stiff pile. The third lobe (*b*) stands erect and compressed alongside the penis. It is very wide, but short baso-distad.

In *Spilomyia* also the more caudal of the lobes of the style is likewise bilobed, but in this case it is brought about simply by an emargination near the apex of the caudal lobe. (See Figures 124 to 126, Plate XVII).

Irregular styles of noteworthy character are the bicornuate condition of a species of *Sphegina* (Fig. 80, Plate XIV) and of *Psilota buccata* (Figs. 33 and 34, Plate XII); and those of *Didea fasciata fuscipes* (Fig. 51, Plate XIII) which are shaped like an amphitheatre, with nearly perpendicular sides; they are very short and present the appearance of having been mashed over and then twisted around in a semicircle.

In *Xanthogramma* the style differs from its nearest ally, *Syrphus*, in having the caudal margin somewhat produced mesad, as a thin plate, reaching well toward that of the opposite side.

In describing the styles, besides base, apex, mesal and lateral, I have used especially caudal and cephalic margins or faces, (Fig. O, Plate IX). These relations are considered the same as those of a leg, with which the style is probably homologous.

PENIS (phallus, Berlese; theca, Wesche; appendage II, III, Newell; copulatory or intromittent organ of authors). The penis is invariably the largest appendage of the postabdomen. It is unpaired and generally considered to represent the fused appendages of segment nine. It arises from the caudo-ventral portion of the ninth segment and is articulated also to the base of segment ten; both to the inflexed and more or less produced, basal corners of the tergite by the sides of its basal rim (Figs. O, Plate IX; 1, *a*, Plate XV; and 34, Plate XII) and to the cephalic margin of the tenth sternite on the caudal part of its basal rim (Fig. 14, Plate XI).

The penis is a complicated organ that may be understood best if we consider it as being composed of two systems: (I) The axial system, composed of the ejaculatory duct and its associated structures and (II) The peripheral system, composed of the penis sheath and its appendages. The latter may be thought of as a hollow cylinder or truncated cone, open at each end, within which the former system lies along the axis. But the two systems do not ordinarily articulate with each other at any point.

The parts of each system will now be considered as follows: I, The axial system: *a*, the ejaculatory process; *b*, the chitinous box; *c*, the ejaculatory hood; *d*, the internal lobes; *e*, the sustentacular apodeme; *f*, the ejaculatory sac and *g*, the ejaculatory apodeme. II, The peripheral system: *h*, the penis sheath and its basal rim; *i*, the cephalic emargination; *j*, the lingula; *k*, the superior lobes and *l*, the inferior lobes.

A. THE AXIAL SYSTEM OF THE PENIS.

The terminal continuation of the ejaculatory duct, called the ejaculatory process, and the associated structures present a surprising variation in the different genera and even in very closely related species. All these parts are evidently in a process of rapid evolution and hence afford excellent specific characters, but yield a very meager amount of data as to phylogeny of groups. The entire known range of variation may be found almost in a single genus.

(a). THE EJACULATORY PROCESS: The orifice of the duct, one of the important landmarks, is often difficult to locate. It varies from a very minute aperture (*Chrysogaster*, *Mesogramma*, *Helophilus*, *Criorhina*, *Microdon*, etc., Figs 37, 38, 41, Plate X; 86, 91, Plate XVI; 97, 129, 130, Plate XIX; 111, 112, 115, 129, Plate XVIII) to a moderate sized one, (*Sphegina*, *Didea*, Figs. 51, *d*, Plate XIII; 75, *d*, 76, Plate XIV; 100, *d*, Plate XIX) to a comparatively large mouth (*Baccha*, *Chilosia*, *Rhingia*, Figs. 21, 25, 26, Plate XI; 3, 4, Plate XV; 5, 11, Plate X; 32, 33, 34, 30, Plate XII; 102, Plate XVII). In position it varies from being sessile on the face of the globular or hood-like chitinous box (*vide infra*) as in *Hammerschmidtia*, *Eumerus strigatus*, *Copestylum marginatum*, *Cynorhina analis*, *Milesia virginiensis*, *Helophilus*, (Figs. 115, 117, Plate XVIII) to being elevated at the apex of a tube, short and delicate in *Helophilus* spp., (Fig. 86, Plate XVI), *Criorhina nigripes* (Fig. 111, Plate XVIII) and *Mesogramma* (Fig. 45, Plate XIII, in some species of which it turns a complete loop before its termination), heavy in *Rhingia*, *Chrysogaster* spp., *Pipiza*, *Sphegina*, (Figs. 40, 41, Plate X; 19, 24, 26, Plate XI; 32, 34, Plate XII; 69, Plate XIV), longer and delicate in *Criorhina nigra*, still longer and heavy in other species of *Criorhina*, and long, very heavy and distorted in *Baccha* sp. In other cases it is continued to the termination of a long, sometimes extremely long and slender tube, single in *Chrysogaster* spp., *Mallota posticata*, *Mixogaster breviventris*, *Crioprora cyanella* (Figs. 118, Plate XVIII; 133, Plate XIX; 36, 37, 38, Plate X); double in *Microdon* and *Ceriodes*, (Figs. 129 to 132, Plate XIX); in the former the two tubes both on the median line, the split transverse, and one tube may be much shorter; in the latter the two placed right and left, the split longitudinal. And from being thus subtended by a rigid, chitinous support, we find variations to a support, chitinous, basad, but delicate, inflated and collapsable at apex, (*Chilosia*, *Syrphus*, *Chrysotoxum*, *Eupeodes* Figs. 27, 29, Plate XII; 49, 50, 53, 59, Plate XIII; 134, Plate XIX); and to a condition in which it is surrounded by a delicate flexible and inflated hyaline membrane as in *Sphaerophoria* (Figs. 1, 60, 63, 64, 67, 68, Plate XV).

(b). THE CHITINOUS BOX: There is often near the apex of the penis, standing mediad, a more or less globose or pyriform or variously shaped expansion called by Berlese the chitinous box (Figs. 27, Plate XII; 49, 50, 56a, 53, Plate XIII; 62, 67, 68, Plate XV; 76, Plate XIV; 91, Plate XVI; 97, 100, 129, 130, Plate XIX; 102, 105, *a*, 127, Plate XVII; 112, 118, *d*, 119, Plate XVIII). This is variously supported as described for the different species, but typically rests on the apex of the sustentacular apodeme (*vide infra*). The ejaculatory duct may pass through such a chitinized body before its termination and the orifice of the duct, when sessile, is usually toward the apex on its cephalic face. When an ejaculatory process is present it is an outgrowth of the chitinous box either from its cephalic face (Figs. 38, 40, 41, Plate X; 45, Plate XIII; 119, 120, Plate XVIII), from its apex (Figs. 1, 60, Plate XV; 27, 28, Plate XII), or as in *Syrphus* and the related genera (Figs. 49, 50, 54, Plate XIII; 67, 68, Plate XV) the box is collar-like, widely open distad, and the ejaculatory process arises from within the box towards its caudal side. When the ejaculatory process is greatly elongated, the chitinous box is often displaced well toward the base of the penis sheath (e. g., *Microdon*, *Ceriodes* and *Mixogaster*, Figs. 129 to 133, Plate XIX).

(c). THE EJACULATORY HOOD: Besides the ejaculatory aperture and process the chitinous box often bears a median structure on the caudal side, that, from its more typical shape, has been called the *ejaculatory hood*. It overhangs the aperture of the duct when it is sessile or on a short process (Figs. 2, 3, Plate XV; 5, 6, 9, 10, 11, Plate X; 13, 18, 19, 21, 23, 25, Plate XI; 27, 30, 32, 35, Plate XII; 40, 41, 47, 48, Plate X; 45, 46, 51, *c*, Plate XIII; 74, 75, 76, *c*, 77, *c*, 81, 82, Plate XIV; 89, Plate XVI; 102, 103, 105, 106, 107, Plate XVII; 111, 112, 113, 114, 115, 119, 120, Plate XVIII; 97, 131, 132, 133, 134, Plate XIX) or, if the process is very long, it may support and protect the apical part of it as in *Chrysogaster* spp. (Figs. 38, 39, Plate X) in *Xylota* spp., and in *Mallota posticata*.

In other cases it is difficult to decide whether to consider the elaborations of the chitinous box an ejaculatory hood (*Syrphus*, *Sphaerophoria*) or internal lobes (*vide infra*) or simply a part of the chitinous box. The ejaculatory hood may be entirely wanting as in *Xylota* spp., *Chilosia*, and *Microdon*. When present it almost always affords a specific character. In some cases it helps to define a genus as in *Paragus*, *Cnemodon*, *Calliprobola*, *Xylota*, *Criorhina*, etc. Or it may serve to show something of the relationships of certain genera as in the *Xylota*, *Cynorhina* and *Criorhina* groups, which show a rather characteristic cordate hood in many of their species, (Figs. 105 to 107, Plate XVII; 111 and 115, Plate XVIII).

A few of the more remarkable developments of the ejaculatory hood are in *Chrysogaster pulchella* where, with the ejaculatory process, it resembles one of a pair of tongs (Figs. 36, 37, Plate X). In *Chrysogaster* generally it is much elaborated, often simulating a bird's head, (Figs. 38, 41, 48, Plate X). In *Teuchocnemus* (Figs. 96 and 100, Plate XIX) it is a long V-shaped affair, and in *Xylota fraudulosa* and *Mallota posticata*

it takes the form of a long, shallow trough that forms a beautifully adapted support for the remarkable ejaculatory processes of those species. It is remarkably long in *Ceriodes* spp., and shows some very interesting specializations in *Mesogramma*. In this genus there is also sometimes a short, erect, subcylindrical process *cephalad* of the ejaculatory aperture that looks very much like an ejaculatory process and would be mistaken for such if one did not follow the ejaculatory duct, which does not open into it.

(d). INTERNAL LOBES: For those appendages or projections of the chitinous box that neither immediately surround and support the ejaculatory duct, as the ejaculatory process does, nor stand in the median caudal position, as the ejaculatory hood does, I have used the term *internal lobes*. These are lateral in position, are paired and are claspers in function. They are at most of two pairs, respectively caudal and cephalic in point of attachment to the apex of the chitinous box. Such lobes are developed in *Pipiza* (Fig. 35, Plate XII), in which they are a pair of erect, narrow plates prolonged into acute points; in *Mesogramma* (Figs. 45, 46, Plate XIII). In *Sphegina lobata* (Fig. 70, *e*, Plate XIV), they are flattened plates; in an unnamed species of *Sphegina* they are remarkably developed and remarkably unsymmetrical cornua as shown in Figure 72, Plate XIV; in *S. petiolata* (Figs. 74 and 75, Plate XIV) and *S. rufiventris* (Figs. 76 and 77) they are symmetrical and not greatly unlike those of *Pipiza femoralis*. In *Baccha* sp. they are large thin plates guarding the sides of the remarkable ejaculatory process. Other examples of the internal lobes are shown in *Pterallastes* and *Teuchocnemis* (Figs. 96, 97, 100, Plate XIX) in *Xylota* spp. (Fig. 106, Plate XVII), *Chilosia* spp., *Sericomyia* (Fig. 109, Plate XVII), *Criorhina* spp. (Figs. 112, 113, Plate XVIII), *Milesia* (Fig. 119), *Mallota posticata* and *Temnostoma* (Figs. 123, 128, Plate XVII).

Besides the external parts certain internal structures have been considered. The gonads and their efferent ducts and accessory glands have not been studied; but the ejaculatory sac, the piston-like ejaculatory apodeme often associated with it, the efferent ejaculatory duct, and the chitinous, reinforcing sustentacular apodeme, (which gives support to the penis, especially to the chitinous box at its apex, and to which muscles attach that serve to rotate and protrude the parts); these parts are generally evident in the cleared preparations, they often show characteristics of systematic value and consequently they have been described in connection with the external genitalia.

(e). THE SUSTENTACULAR APODEME has been called by Wesche the double apodeme, and he states that it is often a paired organ in many families of the Diptera; in others partially fused; and again entirely united on the median line. In the Syrphidæ it is typically a single rod, having its base in segment nine and projecting to a variable distance into the penis along or near the long axis. It does not articulate with the body wall of segment nine, nor with the penis sheath except rarely as in *Sphegina rufiventris* and *petiolata*; but is held in place by muscles,

some of which originate on it and others of which attach to it. At its apex it supports the chitinous box together with any ejaculatory process, ejaculatory hood and internal lobes that may be present. It evidently functions in supporting, reinforcing and directing these latter parts during copulation: at which time they apparently have movements somewhat independent of the penis sheath and its appendages.

Some idea of its variations will be gained from the following statement. It is practically straight and cylindrical in *Chilosia*, *Lasiophthicus*, *Eristalis*, *Volucella*, *Copestylum*, etc., and may be either long and slender as in *Pipiza* and *Hammerschmidtia* or short as in *Baccha* (Note Figures 17, 19, Plate XI; 56, Plate XIII; 67, Plate XV) or long very heavy and enlarged basad, as in *Mesogramma*. Very commonly it is a bent rod, conforming often to the general shape of the penis sheath as in *Allograpta*, *Blera*, *Condidea*, *Brachyopa*, *Tropidia*, *Syritta*, *etc.*, (Figs. 93, Plate XVI, 114, Plate XVIII), or bent at base only as in *Pipiza* spp., (Fig. 35, Plate. XII) or bent to the left at base as in *Chilosia* (Figs. 28, 29, 30, Plate XII). Frequently instead of being cylindrical, it is compressed as in *Milesia*, *Callicera*, *Temnostoma*, *Bachyopa*, *Asemosyrphus* and *Mallota posticata;* sometimes distinctly sword-shaped as in *Melanostoma* and *Cnemodon* spp. It tapers more or less evenly from apex towards the base in *Helophilus* spp. (Fig. 83, Plate XVI). It is commonly expanded at its base as in species of *Chrysogaster*, *Criorhina*, *Triodonta*, *Mesogramma*, *Tropidia*, *Syritta*, and *Asemosyrphus* (Figs. 37, 47, Plate X; 70, Plate XIV), rarely about the middle, as in *Sericomyia* and *Sphegina* sp. (Fig. 76, Plate XIV) and almost always more or less so at its apex in adaptation to the chitinous box. This latter expansion may be noted, for example, in *Paragus*, *Platychirus*, *Allograpta*, *Brachyopa*, *Somula*; *Milesia*, *etc.* (Figs. 5, Plate X; 25, Plate XI, 67, Plate XV; 114, Plate XVIII). Sometimes the expansion has associated spurs or thorns, as in *Pipiza* spp., or it may be flattened and tongue-like, projecting cephalad as in *Syrphus*, *Eristalis* and *Chrysotoxum*, or such tongue may project caudad from the apex as in *Sphaerophoria* and *Sphegina* spp.; or it may be a flattened transverse plate. In a number of cases there are sharp thin keels or ridges running lengthwise of the apodeme probably of use for the attachment of muscles. Such keels may extend full length or over only a part of base, apex or middle. Such a keel is found on the caudal side of the apodeme in *Didea fasciata fuscipes*, and in *Pipiza* spp. (Fig. 25, Plate XI), while a similar ridge occurs on the cephalic face in *Eupeodes volucris* and *Syrphus* spp.

I have not found it in the paired condition in this family, although it is forked near the apex in Rhingia (Fig. 32, Plate XII) and from about the middle, distad, in *Paragus tibialis* (Fig. 11, Plate X); while in *Teuchocnemis* it is forked at the base. In *Pterallastes thoracicus* (Fig. 97, Plate XIX) it is triradiate toward the base, the median ray shorter, and standing more cephalad, the lateral rays extending caudad. In *Sphegina petiolata* (Fig. 75, Plate XIV) it is also split into three forks toward the base, but all three of these forks stand in the median sagittal plane. Rarely the sustentacular apodeme appears to be wanting as in *Microdon*.

(f). THE EJACULATORY SAC is an expansion of the efferent ejaculatory duct at its proximal end. It often takes the form of a bottle or flask and in almost every case has attached to it at its proximal end (the bottom of the flask) a chitinous rod or sclerite which may be called *the ejaculatory apodeme.*

(g). THE EJACULATORY APODEME is often a complicated mechanism and it presents interesting variations that will well reward a complete exposition by some careful investigator. The typical condition of this sclerite appears to be an umbrella or toad-stool shaped piece which attaches to the bottom of the flask-like ejaculatory sac by the end of its handle (base of its stipe) while from the circumference of the base of the flask to the margin of the umbrella or pileus extend numerous delicate muscle fibers. The contraction of these fibers forces the piston-like part of the apodeme (the handle of the umbrella or the stipe of the toad-stool, as one pleases to think of it) into the bottom of the sac, collapsing the latter and expelling its contents with force. Such an umbrella-like arrangement is found in species of the following genera: *Paragus* (Fig. 11, Plate X), *Chrysogaster* (Figs. 36, 37, 41, 47, Plate X), *Calliproobola, Xylota, Spilomyia, Pterallastes, Brachypalpus* and *Temnostoma.*

A somewhat similar mechanism, but with the basal expansion of the apodeme small and knob-like or globular instead of umbrella-like, is found in *Sphegina* (Figs. 75, 76, Plate XIV), *Sericomyia, Hammerschmidtia, Brachyopa. Condidea lata* shows a rather larger basal expansion intermediate between the above and the umbrella-like form. In *Tropidia* and *Xylota* spp., one finds a very gradual and slight enlargement basad. A small curved rod with moderate *distal* expansion either gradual or abrupt, occurs in *Platychirus* spp.,. *Melanostoma* spp., *Chrysotoxum, Syrphus, Xanthogramma, Blera, Baccha.* In *Blera scitula* the rod is unusually long. A small curved rod without either a basal or distal expansion occurs in some species of *Pipiza, Chilosia, Mesogramma, Psilota buccata* (Fig. 33, Plate XII), *Helophilus* spp., *Cynorhina.*

In *Helophilus* spp., *Microdon* spp., *Eumerus strigatus* and *Somula decora* there is a large sub-triangular, flat sclerite with the apex adjoining the ejaculatory sac. In *Temnostoma, Ceriodes* and *Microdon* it is very large, with a short cylindrical handle and a broad, flat, somewhat fan-shaped basal blade. In *Mixogaster breviventris* it is similar with a longer handle and a spade-like blade with sharp shoulders and sides flaring out to a greater width at the base than next the handle.

In *Syritta pipiens* I find a flat, broom-like sclerite not unlike that in some of the species mentioned above; but at the point where the cylindrical "handle" terminates is a transverse piece composed of a median rounded expansion and two wings, the whole very similar in appearance to the head of a thumb screw.

The most elaborately developed ejaculatory apparatus yet noted is that in *Didea fasciata fuscipes.* The apodeme is broom- or spade-like, with a handle not a fourth as long as the expanded part, the latter with rounded shoulders, parallel sides and broader than long; its area nearly as great as that of the tenth tergite. The ejaculatory sac appears to

enclose a chitinized bow or curved bar which expands Y-shaped at each end, at which points many muscles attach. The short handle of the apodeme attaches to the membranous sac opposite the middle of the bow.

I have not found the ejaculatory apodeme in certain species of *Sphegina, Sphaerophoria, Teuchocnemus*, nor in *Eupeodes volucris*.

B. THE PERIPHERAL SYSTEM OF THE PENIS.

(h). THE PENIS SHEATH is usually a heavily chitinized, truncated cone, cylinder or tube, attenuated distad. It has an especially heavy, basal rim, by which it is articulated and rotated. The rim is usually longer cephalo-caudad than in transverse diameter, the cephalic half of the rim almost always about semi-circular, but the caudal part becomes variously angulated against the base of the tenth sternite and the sides likewise swollen or angulated, or with apophyses to the basal corners of the tenth tergite. In some genera the caudal part is bent into quite another plane than the cephalic part. In many of the *Milesinæ* the basal part of the sheath is larger and globose on the cephalic face, the apical part more nearly cylindrical. (Note Figures 3, Plate XV; 83, 89, Plate XVI; 102 to 107, Plate XVII; 112, 115, 119 and 120, Plate XVIII).

The penis sheath is most often smooth and glabrous. But in certain genera it is highly specialized both in vestiture and by keels, tubercles and furrows of various kinds. In most species of *Temnostoma* there is an area of long delicate hairs on each side near the base. In *Criorhina* and *Milesia* there is often a diffused vestiture on the cephalic face of the penis sheath. In *Helophilus* spp. (Figs. 83, 85, 89, Plate XVI), *Tropidia albistylum* (Fig. 91) and certain species of *Xylota* (Fig. 107, Plate XVII) we note long or short heavy hairs, bent basad in such a way as to suggest a tenaceous value, in addition to others scattered promiscuously over the cephalic face of the penis that are more erect and delicate

Irregularities of the surface of the penis sheath are often in the form of transverse, more or less parallel corrugations on its cephalic face, as illustrated in Figures 91, Plate XVI; 102, 103, 123 and 128, Plate XVII; 115, Plate XVIII. They are peculiarly unsymmetrical in *Somula decora* (Fig. 120). Tubercles of various kinds occur—symmetrical (Figs. 111, 127) or unsymmetrical (Fig. 72, *e*, Plate XIV), large (Fig. 113) or small (Fig. 86, Plate XVI); usually on the cephalic face but rarely on the caudal face as in *Pipiza pisticoides* (Figs. 19, 20, *h*, Plate XI), where an extremely thin keel runs lengthwise on the caudal face and in *Eupeodes volucris* where we note characteristic ribbed ridges at the caudo-lateral corners (Figs. 134, *c*, Plate XIX).

Berlese in describing *Eristalis tenax*, divides the sheath into "two canals (epiphallus and hypophallus)" separated by a longitudinal line on each side and supposedly representing respectively the contribution made to this complex appendage by segments eight and nine. I do not believe that these parts have any morphological significance. The

line is, I think, only a reinforced line along which the chitin is heavier. It is not at all constant in the various species. Similar reinforced lines run in various directions across or along the sheath. Note *Sphegina petiolata* (Fig. 75, *x*, Plate XIV), *Criorhina nigripes, umbratilis* and *verbosa* (Fig. 111, *d*, Plate XVIII), *Mallota posticata, M. sackeni, Blera badia* (Fig. 116, Plate XVIII), *Merodon equestris, Somula decora* (Fig. 120, Plate XVIII), *Brachyopa notata*, etc. The penis sheath is typically emarginated at the apex on both cephalic and caudal faces, between which at each side project the so-called lateral arms or wings of the sheath, bearing the inferior and superior lobes at their apices.

(i). THE CEPHALIC EMARGINATION takes a great variety of forms and often shows a specific character. It is most often narrowly or broadly U or V shaped (Figs. 3, Plate XV; 5, 38, Plate X; 20, Plate XI; 35, Plate XII; 50, Plate XIII; 76, Plate XIV; 87, Plate XVI). In *Paragus bicolor* (Figs. 5 and 6, Plate X) the penis sheath about its margin is ornamented with many close-standing short spines.

(j). THE LINGULA. The cephalic emargination may be partly filled by a projection from the sheath that I have called *the lingula* which is also very variable and so of value in specific determination as in *Syrphus* spp., *Blera confusa, Milesia virginiensis, Xylota curvipes*, etc. (Note Figures 47, 48, Plate X; 52, 53, 54, 55, 56, Plate XIII; 86, Plate XVI; 96, Plate XIX). It stands between the inferior lobes as a tongue-like, unpaired, emarginated or paired extension of the penis sheath on the middle line. It may be forked at apex or modified into an apical scoop-shaped notch that may stand in direct opposition to the termination of the ejaculatory duct or, when the latter is elongate, surround and support its base. It is highly developed in *Paragus* (Figs. 5, 6, 11, Plate X). The lingula may in a series of species become so large as to nearly fill the cephalic emargination and since it is often emarginated at its own apex, there are cases where it is difficult to decide whether the apex should be called a lingula or simply the cephalic emargination. (Note *Paragus bicolor*, Figures 5, 6, Plate X).

The emargination on the caudal face of the penis is much less varied in character and, on this account and because of the difficulty of exposing it, has little taxonomic value.

In a few genera, notably *Microdon, Mixogaster* and *Triodonta*, (Figs. 129 and 133, Plate XIX) the penis sheath is completely interrupted on the caudal face, except for a very slight basal rim, and the margins are infolded or rolled entad and free-standing. This is apparently a highly specialized and not a primitive condition.

The penis-sheath usually bears at its apex certain specializations which may take the form of definitely articulated appendages, or which may be simply prolongations of the sheath, itself, without an articulation. Because of the similarity in function and often in appearance and the practical difficulty of telling whether there is an articulation in many cases, I have called both kinds of processes *lobes*—superior lobes when they are disto-caudal in position, inferior lobes when disto-cephalic in position.

Both pairs are present in *Hammerschmidtia ferruginea, Brachyopa notata, Chilosia* spp., (Figs. 27, 30. Plate XII) *Rhingia nasica* (Fig. 32, Plate XII). In *Microdon* and *Mixogaster*, there are neither inferior nor superior lobes (Figs. 129, 130 and 133, Plate XIX).

(k). THE SUPERIOR LOBES are usually larger than the inferior ones and when only one pair is present it is usually clearly the inferior lobes which are wanting. In *Chilosia*, however, the superior lobes are regularly smaller (Figs. 27 to 30, Plate XII). Like the styles these lobes are subject to the greatest modification of shape, size and vestiture. There appears to be considerable correlation between their development and the simplicity of the styles: that is, the more complicated and efficient the styles the less developed are the penis lobes (note *Calliprobola, Sphærophoria, Eupeodes, Sphegina, Xylota, Criorhina*); and when the styles are simple the penis lobes are often highly developed (*e. g., Chilosia, Paragus, Rhingia*). Their more typical form appears to be a compressed, ovate, erect lobe, standing parallel to the sagittal plane and attenuated somewhat distad, (Note Figs. 19, 25, Plate XI; 46, 49, 50, Plate XIII). But from this shape we find the greatest variation, which can best be appreciated by a reference to the accompanying figures. Frequently they are more cylindrical and erect (Figs. 4, Plate XV; 34, Plate XII; and 87, Plate XVI) and may be enlarged distad (Figs. 36 and 37e, Plate X) or much pointed distad (Fig. 113, Plate XVIII) or incurved toward each other (Fig. 83, Plate XVI) enhancing their prehensile value; sometimes with serrations, (Fig. 40, Plate X). Frequently these serrations take the form of a definite ctenidium as shown in Figures 30, 32, Plate XII; 91, 93, Plate XVI; 107, 123, Plate XVII; 111 to 113, Plate XVIII. Many species have poorly differentiated, shapeless or irregular superior lobes very difficult to describe (Note Figures 96, 100, Plate XIX; 102, 104, 127, Plate XVII; 115, 118, Plate XVIII; 86, 89, Plate XVI). They are not infrequently bare but often have developed hairs, bristles, spines, serrations, claws or lamellæ. They are peculiarly drooping behind the penis in *Paragus* (Figs. 6, 9, Plate X) and in *Sphærophoria* (Figs. 1, 60, 63, Plate XV).

(l). THE INFERIOR LOBES arise at the cephalo-lateral corners of the apex of the penis-sheath. They are generally smaller than the superior lobes. They appear to be best developed in *Paragus*, (Figs. 5, 6, 11, Plate X), *Chrysogaster*, (Figs. 36 to 39), *Chilosia* (Figs. 27 to 30, Plate XII), and *Pipiza*, (Figs. 18, 19, 21, 23, 25, 26, Plate XI), and *Blera* (Figs. 115, 117, Plate XVIII). They are often more or less horn-like, though not infrequently simple lamellæ-like projections of the corners of the penis-sheath.

ASYMMETRY.

Typically, the asymmetry in this family is very strictly confined to the last segment of the preabdomen and the segments of the postabdomen, cephalad of the tenth. But in many species this tendency has spread also to the tenth urite and to the genital appendages. When unsymmetrical it is almost always the left side or the left appendage

that is shortened or toward which the parts are bent. Most often the cerci and styles are affected while the penis and its parts remain perfectly symmetrical; not infrequently both the former and latter take part in the asymmetry and in other cases, curiously enough, the penis and its appendages are unsymmetrical, while the styles and cerci are not or but slightly so. All kinds of combinations occur as the following examples will show. The cerci alone are unsymmetrical in *Microdon* spp. (Fig. 129, Plate XIX). The styles alone in *Blera scitula, Hammerschmidtia ferruginea* and *Ceria signifera.* The superior lobes only in *Mesogramma subannulata.* The inferior lobes only in *Chilosia* spp. (Figs. 27 to 29, Plate XII). The internal lobes only in *Mesogramma parvula.* The ejaculatory process alone in *Baccha* spp. The sustentacular apodeme alone in *Chilosia cyanea* (Fig. 30, Plate XII). The cerci and styles both are slightly unsymmetrical in *Crioprora cyanella,* (Fig. 118, Plate XVIII), *Blera badia,* (Fig. 116, Plate XVIII) and *Chrysogaster pulchella* (Fig. 37, Plate X). The cerci slightly and the styles very much distorted in *Sericomyia* (Figs. 108, 109, Plate XVII), *Criorhina verbosa, Xylota* spp. (Figs. 104 to 107, Plate XVII) and *Hammerschmidtia.* The cerci are very unsymmetrically placed and the styles only slightly affected in *Xylota curvipes* and *flavitibia.* Both cerci and styles are much affected in *Calliprobola* (Figs. 3, Plate XV; 102 and 103, Plate XVII). The cerci, styles and superior lobes are all unsymmetrical in *Chrysogaster* sp. (Figs. 40 to 42, Plate X), and *Temnostoma venusta* and *bombylans.* The cerci, styles and ejaculatory hood in *Xylota ejuncida* and *obscura* (Fig. 107, Plate XVII), *Condidea lata* and *Teuchnocnemis* (Figs. 96 and 98 to 100, Plate XIX). The cerci, styles, superior and inferior lobes of *Pterallastes thoracicus* (Figs. 97, 101, Plate XIX). The cerci, styles, ejaculatory hood and superior lobes of *Xylota subfasciata* (Fig. 105, Plate XVII). The most unsymmetrical parts that I have seen are those of a species of *Sphegina,* in which practically every part is unsymmetrical, and most of them very highly so--cerci, styles, superior, inferior and internal lobes, penis sheath, ejaculatory hood and ejaculatory process.

FUNCTIONS.

The organs described above (the postabdomen and its appendages) appear to have evolved in correlation with several different functions, in the probable order of their importance as follows:

1. Introducing the germ cells to the vagina of the female.
2. Clasping or holding the female during mating.
3. Mechanical protection of the parts.
4. Sensation.

It is surprising to note the variety of structures utilized in what one would suppose to be the very homogeneous operation of introducing the spermatozoa to the vagina. In many cases there is simply a larger or smaller aperature on the face of the ejaculatory hood or chitinous box near the apex of the penis. In other genera and species we find this aperature elevated to the end of a long or short, heavy or slender,

cylindrical or clavate or tapering, and membranous or highly chitinized tubule, the so-called ejaculatory process. The termination of such ejaculatory apparatus may be in an inflatable membrane, or between spinose or serrated lips or a simple aperature of varied size and shape. Even in the species of the same genus these organs may vary tremendously (cf. *Xylota bicolor* and *Xylota vecors*, for example). (See also under ejaculatory process, above). It will be very surprising if these structures are not found to have correlated peculiarities in the females.

The necessity of clasping and holding the female during mating has been most fruitful in producing variations of the appendages. The cerci alone appear not to have taken part in this variation except in rare cases. The styles have developed the greatest variety of structures for the clasping function. Not only does the shape of the parts vary, but they are greatly enhanced in efficiency by the specialization of the vestiture, especially over their mesal faces, toward the apex. This begins as a stiffening of the hairs, accompanied by shortening; the culmination of the process results in very heavy, sharp or dull pegs, sometimes scarcely longer than their diameter. Frequently the styles are bilobed and either caudal or cephalic lobe may be of most value as a clasping organ. Besides the vestiture one or other of the lobes frequently develops a tooth or claw or finger, of endlessly-varied shape. Rarely the inflexed sides of the tenth tergite are prolonged into processes, evidently of use in this connection (*Volucella*, *Microdon*). Again as in *Tropidia* and *Sphegina*, there are processes or bristles on the fifth sternite, which assist in grasping the abdomen of the female. Various parts of the penis-sheath, its lobes and appendages have been adapted for prehension. The most important of them are the superior lobes, and the inferior lobes; but in many species the internal lobes connected with the elaboration of the ejaculatory hood are especially important in this respect. Even the ejaculatory hood itself is sometimes adapted for grasping and the various bristles and keels or processes of the penis-sheath, described in the above pages, doubtless often have a prehensile value.

For the mechanical protection of the parts, the heavily chitinized sternites and tergites of the postabdomen, especially nine and ten, are well adapted. Of even greater importance is the introversion of the base of the postabdomen between the terminal sternite and tergite of the preabdomen, to form a genital pouch. (See above). Contributing toward the investment of the delicate appendages are also the down-bent sides of the terminal tergite of the preabdomen (the fifth or sixth) and the basal segments of the postabdomen on the left.

The only organs which would appear from gross dissection to have a sensory function are the cerci. The fact that they are, I believe, without exception wholly or partly exposed even when the other parts are all well retracted beneath heavy protecting sclerites, and the nature of the hairs on their exposed surfaces, which are long and arise generally from quite conspicuous rings, seem to point to them as the "antennæ" of the postabdomen; in this family, probably exclusively tactile.

TAXONOMIC VALUE OF THE GENITALIA.

A character to be really satisfactory for taxonomic purposes must meet several requirements. First and most important, it must be constant intraspecifically; or, if it vary, at least its variations in a given species must not overlap the development of the structure in the related species. Second, it must show great variation interspecifically, the greater the better. The number of species is so great in the class Insecta, that a really intricate structure is demanded if we are to find characters for all sufficientlly different to permit of recognizable description. Third, the character should be one that is readily available.

It is axiomatic that all parts of living organisms vary. But it appears that in the cases where they have been carefully tested for variability, the genitalia show a constancy greater than that of almost any other external part of the insect, possibly because they have assumed a position whereby they are practically internal and so protected from the stimulus of the external environment. I have not examined them by the hundreds or thousands, but in several common species of different genera, I have mounted from a dozen to twenty individuals, collected from points as remote as Mississippi, British Columbia, North Carolina, California, Minnesota, Maine, Ohio, Montana, Arizona, Michigan and Colorado. While occasionally one may find a slight variation in the number of hairs or bristles on a given part or a slight variation in the shape of a margin, they are always so remarkably similar that any one would place them together without the least hesitancy.

In regard to variation between species I do not believe any group of structures will be found, that so admirably fulfills this requirement. Nature seems to have run wild in developing many of the structures one finds in the terminal, abdominal appendages of insects.

In regard to the availability of the characters of the genitalia, it must be admitted that this is the chief, if not indeed the only, real objection to their use in taxonomy. The parts are in this family completely retracted except during mating. Undoubtedly the preliminary preparation, such as relaxing and clearing in potash, that is required will at once limit the number of students who will make use of these characters. But it is hardly complimentary to entomological perseverance, if we

allow difficulties of this nature to be an ultimate bar to the utilization of the greatest single group of taxonomic characters that insects possess. The further hopeful feature is that, when these parts have been carefully worked out for a group, subsequent students will often be able to make use of the characters, without clearing, by simply comparing the opaque parts of the fresh or relaxed specimen.

It may be objected that the process of removing the genitalia mutilates the specimen. But if the specimen is fresh or well-relaxed and one uses moderate care, the removal of the modified terminal segments is not a matter of any seriousness. All the parts generally used in taxonomy are left intact; and a specimen with the mounted genitalia unmistakably associated with it is in my opinion not damaged but greatly enhanced in value.

Another criticism of the genitalic method is that, in the process of mounting, especially in treating with caustic potash, the parts are likely to be variously distorted and so lead to serious taxonomic errors. This criticism should be anticipated in every investigation and any possible variable effect of the method of preparation checked by examining the parts before clearing and by preparing in several different ways. It would seem that the fact that numerous mounts made at different times and by varying methods are identical to the most minute detail, is sufficient answer to this criticism, so far as the Syrphidæ are concerned. In fact the parts herein considered are almost all heavily chitinized and not likely to be distorted either by clearing or by the pressure of the cover glass. Of course one would not derive taxonomic characters from such parts as the delicate, inflatable membrane terminating the ejaculatory duct in *Sphærophoria*, for example.

One matter of genuine difficulty is that it is often hard to define the characters that give to these parts a peculiar and easily recognizable *facies*. The appendages are generally very irregular figures of three dimensions; and in the more complex forms nothing short of a figure of the parts in two or more aspects, together with a careful description is adequate to convey a real impression of their makeup. But however difficult the interpretation of these parts may be they have the essential points of intraspecific constancy and interspecific variability to a degree hardly equaled by any other set of organs.

A point of great value in the use of these structures is their usefulness in the case of mutilated specimens. Alcoholic, rubbed, or broken specimens are often wholly unintelligible from the standpoint of the characters generally employed. The genitalia, however (protected within the hard, enveloping sclerites of the abdomen), are apt to be the last parts to be injured. Interesting and valuable applications of this knowledge will at once occur to every one; as in the examination of the contents of avian or amphibian stomachs, or the elucidation of valuable, but poorly-preserved, type specimens or others of historic value.

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EXPLANATION OF PLATES.

ABBREVIATIONS AND GLOSSARY.

Except in Figures A to H, Roman numerals are used to indicate the successive urites, both for the tergites and for the sternites.

Caud. Int. L. . . . . . . *Caudal internal lobes.*
C. Emarg. . . . . *Cercal emargination*, the emargination at apex of tergite ten, into which the cerci are received to a varying degree.
Ceph. E. . . . . *Cephalic emargination*, an emargination on the cephalic face of the penis sheath near the apex.
Ceph. Int. L. . . . . . . *Cephalic internal lobe.*
Cer. . . . . *Cercus.*
C. B. . . . . *Chitinous box*, a chitinous mass at the apex of the penis through which the ejaculatory duct may pass and to which are articulated or joined the ejaculatory hood, the ejaculatory process and the internal lobes.
Ejac. Apod. . . . . *Ejaculatory apodeme*, a chitinization attached to the ejaculatory sac.
Ejac. Dct. . . . . *Efferent ejaculatory duct.*
Ejac. Hd. . . . . *Ejaculatory hood*, a projection from the chitinizations surrounding the ejaculatory duct which stands caudad of the ejaculatory duct on the median line.
Ejac. Pr. . . . . *Ejaculatory process*, a prolongation from the chitinous box, which surrounds the ejaculatory duct in cases where the orifice of the duct is elevated above the chitinous box.
Ejac. Sac. . . . . *Ejaculatory sac.*
G. P. . . . . *Genital pouch*, a depression near the apex of the venter of the abdomen, into which the penis, styles, etc., are received when not in use.
Inf. Lob. . . . . *Inferior lobe*, the more cephalic of two pairs of lobes or appendages arising from the apex of the penis sheath.
Int. Lob. . . . . *Internal lobe*, one of two pairs of lobes or appendages associated with the chitinous box or with other chitinizations about the ejaculatory duct.
Lingula. . . . . A median tongue-like process from the apex of the penis sheath on its cephalic face.
L. Caud. Int. L. . . . *Left caudal internal lobe.*
L. Cer. . . . . *Left cercus.*
L. Inf. Lob. . . . . *Left inferior lobe.*
L. S. . . . . *Spiracle* of the left side.
L. Sup. Lob. . . . . . *Left superior lobe.*
Postabdomen . . . . . . The caudal four or five urites of the abdomen that have been greatly modified in conformity with the genital appendages.
Post-anal Hood. . . . . A median ornamental expansion standing caudad of the anus and between the styles.
Preabdomen. . . . . The unmodified, four or five urites of the cephalic part of the abdomen.
R. Caud. Int. L. . . . *Right caudal internal lobe.*
R. Cer. . . . . *Right cercus.*
R. Ceph. Int. L. . . . *Right cephalic internal lobe.*
R. Inf. Lob. . . . . *Right inferior lobe.*
R. S. . . . . *Spiracle* of the right side.
R. Sty. . . . . *Right style.*
R. Sup. Lob. . . . . . . *Right superior lobe.*
S. . . . . *Sternite.*
Sc. . . . . *Scutellum.*
Stern. . . . . *Sternite.*
Sty. . . . . *Style.*

Sup. Lob. ......*Superior lobe*, the more caudal of two pairs of lobes or appendages arising from the apex of the penis sheath.
Sust. Apod ....*Sustentacular apodeme*, an internal, chitinous rod lying along the axis of the penis.
T ....*Tergite*, the tergum of an abdominal segment.
Terg ....*Tergite*.
U ....*Urite*, an abdominal segment.
Sternal Cornua.... A pair of processes standing caudad of the anus and mediad of the styles.
Sup. Lob ....*Superior lobe*, the more caudal of two pairs of lobes or appendages arising from the apex of the penis sheath.

Other legends are explained in connection with the several Figures. The number preceded by * in the explanation of the Figures is the serial number of the specimen from which the illustration was made.

PLATE IX.

Fig. A. Dorsal view of abdomen of *Chilosia* sp., with the genitalia in the retracted position.
Fig. B. The same in ventral view.
Fig. C. Tip of abdomen of *Temnostoma* sp., with the genitalia in the retracted position. Dorsal view.
Fig. D. The same in ventral view.
Fig. E. Tip of abdomen of *Microdon* sp., with the genitalia in the retracted position. Dorsal view.
Fig. F. Tip of abdomen of *Syrphus arcuatus*, with the genitalia in the retracted position. Ventral view.
Fig. G. The same in dorsal view.
Fig. H. Tip of abdomen of *Chrysotoxum* sp., in ventral view, showing the genitalia in the retracted position.
Fig. I. The same in dorsal view.
Fig. K. Dorsal view of abdomen of *Mesogramma geminata*, with the genitalia partly exposed.
Fig. L. Tip of abdomen of the same more enlarged and in ventral view.
Fig. M. Tip of abdomen of *Eristalis* sp. from the right side, with the genitalia and postabdomen extended to show especially the course of the right lateral conjunctiva and the position of the spiracles.
Fig. N. Tip of abdomen of *Eristalis* sp. from the left side, with the postabdomen and genitalia extended to show the course of the left lateral conjunctiva and the position of the spiracles.
Fig. O. A diagrammatic representation of the various parts represented in the male genitalia of the Syrphidæ, dextro-cephalic view; *A*, cephalic margin of the style; *B*, caudal margin of the style.

PLATE X.

Fig. 5. *Paragus bicolor;* ventro-cephalic view of genitalia (*132). *a*, apophysis from penis sheath to base of superior lobes, equivalent to the lateral wings of the penis sheath in other genera; *b* and *c* caudal and cephalic lateral horns, respectively, of penis sheath at each side.
Fig. 6. The same in lateral view. Captions as in Figure 5. The short, slender spine from the apex of the sustentacular apodeme is shown in black between the base of the cephalic horn of penis sheath (*c*) and the base of the inferior lobes.
Fig. 9. *Paragus quadrifasciatus*, disto-lateral view of genitalia (*183). *b*, the two teeth from the apex of the sustentacular apodeme.
Fig. 10. The same in distal view. *b*, the more caudal of the two teeth from the sustentacular apodeme.
Fig. 11. *Paragus tibialis*, ventro-cephalic view of genitalia (*175).

Fig. 36. *Chrysogaster pulchella;* caudo-lateral view of genitalia (*131). *a*, thorn on inferior lobe a little laterad of the cephalic margin; *c*, thorn on cephalic margin of inferior lobe at point of fusion of the two lamellæ; *d*, tooth on the mesal lamella of inferior lobe; *e*, the deer's-head-like, disto-caudal termination of the superior lobe.

Fig. 37. The same in cephalo-lateral aspect; *a*, *c*, and *e* as in Figure 36; *b*, thumb-like projection at disto-caudal angle of inferior lobe; *f*, the joint of basal rim of penis at the point of articulation with the tenth tergite; *g*, caudo-basal continuation of the inferior lobe to the penis rim; *h*, slender apophysis of left side of penis rim to base of tenth sternite.

Fig. 38. *Chrysogaster parva;* genitalia (*254) from the right side. *a* and *b* bispurred, disto-caudal termination of the inferior lobe; *c*, more cephalic, apical finger of superior lobe; *d* and *e*, the two spurs at the apex of the more caudal finger of the superior lobe; *f*, the "breast" of the bird-head-like ejaculatory hood.

Fig. 39. The same, in caudo-distal aspect. Captions as in Figure 38.

Fig. 40. *Chrysogaster* sp.; ventro-cephalic view of genitalia (*253).

Fig. 41. The same, in cephalo-lateral aspect. *a*, basal offset of style.

Fig. 42. A disto-caudal view of cerci and styles. Captions as in Figure 41.

Fig. 47. *Chrysogaster nigrovittata;* genitalia (*162) in cephalic aspect. *d*, opening of the ejaculatory duct; *f*, serrate flaps, overhanging the opening of the ejaculatory duct.

Fig. 48. The same, from the right side. *a*, emargination of the tenth tergite at base of style.

PLATE XI.

Fig. 12. *Pipiza nigribarba;* cephalic view of styles, post-anal hood and apex of penis (*200). *d*, the termination of the ejaculatory duct. The heavy bristles shown on the left style arise on the caudal face of the style and their bases should not be shown in this view nor in Figure 14.

Fig. 13. The same, in distal aspect. *a*, the sclerites communicating between the styles, the tenth sternite and the post-anal hood. The post-anal hood is shown in caudal aspect between the styles and the parts marked *a*, at each side, and the cerci and apex of the penis at the ends.

Fig. 14. The same, in cephalic aspect; with the penis displaced cephalad, showing the tenth sternite and cephalic aspect of the post-anal hood. *a*, as in Figure 13; *b*, pilose side walls of post-anal hood; *c*, the free-standing base of the post-anal hood.

Fig. 15. *Pipiza pisticoides;* disto-cephalic view of the post-anal hood and left style (*135). *a*, the distal, upturned end of the post-anal hood; *b*, semi-globular, spinose crown of the post-anal hood, one of the best characteristics of the species; *c*, squarish prominence of the caudal face of post-anal hood; *d*, the free-standing basal prolongations of the membranes on the cephalic face of hood; *e*, the apophysis-like rod from caudal face of the hood to the tenth sternite and styles, and forming the entire support of the hood; *f*, the double, drooping, median keel of cephalic face of hood; *g*, angular apophysis near base of style.

Fig. 16. The same, in dorso-caudal aspect. Captions as in Figure 15.

Fig. 17. *Pipiza pulchella;* dorso-caudal view of the genitalia (*134); the penis shown in cephalo-lateral aspect. *a*, chitinous box at apex of sustentacular apodeme; *c*, cephalic ramus of the inferior lobes; *d*, ear-like flaps at apex of post-anal hood. APOD is an error for SUST. APOD.

Fig. 18. The same in cephalo-lateral view; the penis in about a distal view. Captions as in Figure 17.

Fig. 19. *Pipiza pisticoides;* genitalia from the right side; the right style removed to expose the post-anal hood. Captions *a* to *g* as in Figure 15; *h*, sharp, median keel on caudal face of penis; *i*, short spur from apex of sustentacular apodeme.

Fig. 20. The same in cephalo-lateral aspect. Captions as in Figures 15 and 19.

Fig. 21. *Pipiza australis;* ventro-cephalic view of genitalia (*223).

Fig. 22. *Pipiza calcarata;* dorsal view of apices of cerci and arms of tergite ten; the styles and post-anal hood seen in caudal aspect (*138). *a*, the upturned distal end of the hood; *b*, the concave side walls of the hood; their cephalic margins, after a sharp turn caudad, fuse just above the letter *c*, in the Figure; *d*, chitinized supporting bow of the side walls *b*; *e*, pilose convexity on the apophyses from base of hood, connecting with base of the style and the apex of the tenth sternite on each side and constituting the only supports of the hood; *k*, distal arms of the tenth sternite.

Fig. 23. The same; genitalia in side view. *f*, the free-standing, basal extensions of the setose membrane (*g*, Figure 24); *g*, the baso-cephalic continuation of the framework margining the upturned part of the hood. Other captions as in Figure 22.

Fig. 24. The same; ventro-cephalic view of genitalia. *g*, setose membrane stretching across the cephalic face of the hood; *i*, tendon-like rod from base of hood into the tenth segment; *m*, aperature to the inside of the hood. Other captions as in Figures 22 and 23.

Fig. 25. *Pipiza (Heringia) heringi;* ventro-cephalic view of genitalia (*198).

Plate XII.

Fig. 27. *Chilosia similis;* ventro-cephalic view of genitalia (*387 and 412). *b*, cephalo-lateral keel of styles; *c*, caudo-lateral keel of styles.

Fig. 28. *Chilosia tristis;* ventro-cephalic view of genitalia (*370). *a*, the caudal excavation on blade of left inferior lobe. Other captions as in Figure 27.

Fig. 29. *Chilosia pallipes;* ventro-cephalic view of genitalia (*415). Captions as in Figure 27.

Fig. 30. *Chilosia cyanea;* ventro-cephalic view of genitalia (*402).

Fig. 31. *Rhingia nasica;* distal view of genitalia (*320). The right style omitted to expose the penis lobes.

Fig. 32. The same, in cephalic view. Right half of urite ten and right style omitted. *a*, swollen lateral portion of basal rim of penis.

Fig. 33. *Psilota buccata;* genitalia (*140) in ventro-cephalic view. *A*, median ramus of left style; *B*, lateral ramus of right style.

Fig. 34. The same, more enlarged and in cephalo-lateral aspect. *A*, as in Figure 33; *B*, lateral ramus of left style; *a*, apophysis from the right side of basal rim of penis to the tenth sternite; *b*, thickened lateral margins of tenth sternite; *c*, median split in the tenth sternite; *d*, the less chitinized median portion of the tenth sternite; *e*, catenulated area of superior lobe.

Fig. 35. *Pipiza femoralis;* cephalo-lateral view of genitalia (*137). *a*, tongue-like extension from basal rim of penis to the base of tenth sternite; *b*, palmate lobe at cephalo-distal angle of superior lobe; *c*, prominent teeth at caudo-distal corners of superior lobes; *d*, boot-like apophysis from base of right superior lobe to the chitinous box at apex of sustentacular apodeme; *e*, lateral emargination of apex of penis sheath; *f*, cephalo-lateral arms or wings of penis-sheath.

Plate XIII.

Fig. 43. *Mesogramma geminata;* dorso-distal view of genitalia and tenth tergite. (*233).

Fig. 44. The same, in cephalo-ventral aspect (*232).

Fig. 45. *Mesogramma polita;* ventro-cephalic aspect of genitalia (*321).

Fig. 46. The same, from the right side.

Fig. 49. *Didea laxa;* lateral view of genitalia (*154).

Fig. 50. The same, in cephalic aspect.

Fig. 51. *Didea fasciata fuscipes*, caudo-distal view of genitalia (*204). *a*, central lobe of trituberculate ejaculatory hood; *bb*, earlike tuberosities of ejaculatory hood; *cc*, the overhanging flaps of the collar-like, chitinous box; *d*, the opening of the ejaculatory duct or ejaculatory process.

Fig. 52. *Syrphus arcuatus;* ventro-lateral view of genitalia (*210). *b*. spurs at cephalic ends of collar-like chitinous box.

Fig. 53. *Syrphus xanthostomus;* lateral view of genitalia (*201). *b*, spurs at cephalic ends of collar-like chitinous box; *c*, apical tongue of sustentacular apodome.

Fig. 54. *Syrphus knabi;* disto-ventral view of genitalia (*205). *b* and *c*, as in Figure 53; *a*, the cephalic keel of sustentacular apodome.

Fig. 55. The same, in lateral view. Captions as in Fig. 54.

Fig. 56. *Syrphus amalopis;* lateral view of genitalia (*209). *a*, erect chitinous box.

Fig. 57. *Xanthogramma tenuis* Osburn (=Syrphus oronoensis Mtclf.) disto-lateral view of genitalia (*208).

Fig. 58. *Chrysotoxum derivatum;* caudo-distal view of genitalia (*201).

Fig. 59. *Chrysotoxum pubescens;* caudo-distal view of genitalia (*202).

PLATE XIV.

Fig. 69A. *Sphegina lobata;* dorsal view of preabdomen, the genital appendages seen in their cephalic aspect. The course of the left longitudinal tracheal trunk is shown from spiracle 5 to spiracle 8.

Fig. 69B. *Sphegina lobata;* ventral view of preabdomen, the genital appendages seen from their caudal aspect (*18). *a*, ejaculatory hood; *b*, apex of ejaculatory process; *c*, superior lobes; *d*, slightly thickened, apical rim of penis-sheath; *e*, chitinous box; *f*, caudal ramus of right style; *s*, point of fusion of ejaculatory process to ejaculatory hood; *t*, tongue-like caudal projection from between the bases of the internal lobes.

Fig. 70. The same, genitalia from the right side. Captions as in Figure 69, except *e*, the internal lobes arising from the chitinous box; *v*, angle of sustentacular apodome, beyond which it widens, in cephalic aspect.

Fig. 71. *Sphegina* sp.; dorsal view of terminal segments of the postabdomen, showing the caudal aspect of the appendages (*222). *a*, the cephalic ramus of the right style.

Fig. 72. The same, genitalia from the left side. *aa*, cephalic rami of the styles, offset mesad from the base of the caudal ramus as shown to the right of the letter *c; bb*, the lever-like arms of the tenth sternite, which operate between penis rim and apices of cephalic rami of the styles; *e*, basal swelling of the cephalic face of the penis sheath.

Fig. 73. *Sphegina petiolata;* ventral view of preabdomen, the genital appendages shown from their caudal and distal sides, (*17 and 170). *a*, an anomalous, caudal lobe of the penis-sheath; *c*, the acute, cephalo-distal angle of the superior lobe; *o*, the membranous lobe projecting from under the fifth sternite.

Fig. 74. The same, in disto-lateral view. *s*, caudo-internal lobe of right side, seen through the lateral wing of the penis-sheath; *k*, chitinous arm reinforcing the bonnet of the ejaculatory hood; *o*, caudo-distal angles of superior lobes. Other captions as in Figure 73.

Fig. 75. Ventro-cephalic view of the same. *b*, rudimentary inferior lobes?; *d*, the termination of the ejaculatory duct; *f*, the open cephalic face of the ejaculatory hood; *s*, transverse septum between cephalic face of ejaculatory hood and opening of ejaculatory duct; *m*, cephalic ray of sustentacular apodome; *n*, median or principal ray of sustentacular apodeme; *x*, a reinforced line across the cephalic face of the penis-sheath. (other captious as in Fig. 73).

Fig. 76. *Sphegina rufiventris;* cephalo-lateral view of genitalia (*4, 5, 7); *a*, the cephalic emargination of the penis-sheath; *c*, bonnet-like hood overhanging the ejaculatory process.

Fig. 77. The same; a ventral view of the apex of the preabdomen showing the genitalia in distal view (*168); *a* and *c* as in Figure 76; *b*, interlocking tubercles on the mesal face of the superior lobes; *d*, notch in caudal margin of sternite five above which is shown the group of characteristic heavy black spiny hairs.

Fig. 78. *Sphegina* sp. (*24). Ventral view of sternite five, the genitalic appendages seen in their caudal aspect; *a*, the caudal ramus of the right style.

Fig. 79. The same, right style more enlarged.

Fig. 80. *Sphegina* sp. (*23). Ventral view of sternite five, the appendages seen in caudal aspect.

Fig. 81. *Sphegina infuscata;* cephalo-lateral view of the genitalia (*169). *a*, peculiar larynx-like ring or shelf at apex of sustentacular apodeme.

Fig. 82. The same, in disto-caudal view (*19).

Plate XV.

Fig. 1. *Sphaerophoria* sp.; male genitalia (*38) in ventro-lateral aspect, slightly exposed; *a*, an apophysis from tergite ten to the penis rim; *b*, finger-like projection at cephalo-distal corner of style; *c*, sharp tooth terminating the submarginal keel of the style; *d*, the submarginal keel; *e*, a sclerite almost completely separated from tergite ten, at its baso-lateral corners.

Fig. 65. *Sphaerophoria scripta;* cephalo-lateral aspect of genitalia (*173).

Fig. 64. *Sphaerophoria* sp.; genitalia (*263), in cephalo-lateral aspect.

Fig. 62. *Sphaerophoria sulphuripes;* genitalia (*142) in cephalic aspect.

Fig. 63. The same; in lateral view.

Fig. 66. *Sphaerophoria menthastri;* genitalia (*257), cephalo-lateral view of styles.

Fig. 60. *Sphaerophoria* sp.; lateral view of genitalia (*149).

Fig. 61. The same; in cephalic aspect.

Fig. 67. *Sphaerophoria micrura;* cephalic view of genitalia (*145).

Fig. 68. The same; in caudo-lateral aspect, showing also the terminal urites.

Fig. 4. *Xylota bicolor;* cephalo-lateral view of genitalia (*277). See also Fig. 110, Plate XVII.

Fig. 2. *Chrysogaster* sp.; caudal view of genitalia (*292); *a*, cephalic margin of superior lobe.

Fig. 3. *Calliprobola crawfordi;* cephalic aspect of genitalia (*285).

Plate XVI.

Fig. 83. *Helophilus similis;* ventro-cephalic view of genitalia (*245). *a* and *b* mark the caudal and cephalic lobes respectively of the style in this and following Figures.

Fig. 84. The same, side view of cercus and style.

Fig. 85. *Helophilus obsoletus;* ventro-cephalic view of genitalia (*249), the left style omitted.

Fig. 86. *Helophilus bilinearis;* ventro-cephalic view of genitalia (*243); left style in part omitted.

Fig. 87. *Helophilus latifrons;* ventro-cephalic view of genitalia (*246); right style omitted.

Fig. 88. The same, side view of style and cercus.

Fig. 89. *Helophilus lunulatus;* ventro-cephalic view of genitalia (*244).

Fig. 90. *Helophilus* sp.; lateral view of genitalia (*242).

Fig. 91. *Tropidia albistylum,* ventro-cephalic view of genitalia (*256); *a*, basal lobe on cephalic side of caudal lobe of style; *b*, cephalic lobe of style.

Fig. 92. The same, lateral view of cercus and style, showing the outline of the several lobes. Captions as in Figure 91.

Fig. 93. *Tropidia quadrata;* ventro-cephalic view of genitalia (*288). Captions as in Figure 91. Apod is an error for Sust. Apod.

Fig. 94. *Helophilus modestus* (= *Tropidia cooleyi* Seemans, cotype) lateral view of genitalia (*270).

Fig. 95. *Tropidia quadrata;* lateral view of the apex of preabdomen and genitalia to show especially the specialization of sternite five.

Plate XVII.

Fig. 102. *Calliprobola aldrichi;* ventro-cephalic aspect of genitalia (*284).

Fig. 103. *Calliprobola pulcher;* ventro-cephalic aspect of genitalia (*283).

Fig. 104. *Xylota vecors;* ventro-cephalic view of genitalia (*281); *d*, erect caudal lobe of the style; *a*, cephalic lobe of the style.

Fig. 105. *Xylota subfasciata;* ventro-cephalic view of the genitalia (*276); *a*, chitinous box. Other captions as in Figure 104.

Fig. 106. *Xylota chalybea*, ventro-cephalic view of the genitalia (*278); *a*, hook or claw of left internal lobe. Other captions as in Figure 104.

Fig. 107. *Xylota obscura;* ventro-cephalic view of the genitalia (*282); *f*, chitinous box, homologous to that shown at *a*, in Figure 105. Other captions as in Figure 104.

Fig. 108. *Sericomyia militaris;* cephalic view of genitalia (*224). *a*, the small bonnet of the ejaculatory hood. On the right of the letter *a*, is shown the right cercus; while at either side of the bonnet is the erect internal lobe. Between the inferior lobes is the lingula.

Fig. 109. The same, from the left side.

Fig. 110. *Xylota bicolor;* lateral view of genitalia (*277). Compare Plate XVI, Figure 4. Captions as in Figure 104.

Fig. 122. *Spilomyia interrupta;* ventro-cephalic view of genitalia (*255); *a*, caudal lobe of style; *b*, cephalic lobe of style.

Fig. 123. *Temnostoma venusta;* ventro-cephalic view of genitalia (*295). *d*, caudal lobe of style; *e*, cephalic lobe of style.

Fig. 124. *Spilomyia longicornis;* lateral view of right style (*229). Captions as in Figure 122.

Fig. 125. *Spilomyia quadrifasciata;* lateral view of right style (*228). Captions as in Figure 122.

Fig. 126. *Spilomyia fusca;* genitalia (*227) from the right side. Captions as in Figure 122.

Fig. 127. The same, in ventro-cephalic view. Captions as in Figure 122.

Fig. 128. *Temnostoma aequalis;* ventro-cephalic view of genitalia (*294). *k*, baso-mesal keel of superior lobe. Other captions as in Figure 123.

Plate XVIII.

Fig. 111. *Criorrhina nigripes;* ventro-cephalic view of genitalia (*310). *a*, caudal lobe of right style; *b*, cephalic lobe of style; *c*, mesal, thumb-like process from caudal lobe of style; *d*, median pair of keels on penis-sheath; *e*, lateral pair of keels on penis-sheath; *x*, characteristic ctenidium of superior lobes.

Fig. 112. *Criorrhina* sp. (*312); ventro-cephalic view of genitalia. Captions as in Figure 111.

Fig. 113. *Criorrhina* sp. (*313); ventro-cephalic view of genitalia. Captions as in Figure 111.

Fig. 114. *Blera scitula;* cephalic view of left style and penis (*311); *f*, distal cap or pileus of superior lobe.

Fig. 115. *Blera notata;* cephalic view of genital appendages (*321), the right style omitted; *a*, erect caudal lobe of style; *b*, cephalic lobe of style; *c*, baso-cephalic thumb or process from caudal lobe of style; *e*, emargination between caudal and cephalic lobes of style; *k*, lateral keel of lingula.

Fig. 116. *Blera badia;* ventro-cephalic view of genitalia (*301). Captions as in Figure 115.

Fig. 117. The same, apex of penis more enlarged. *k*, basal, elevated, continuation of lingula; *o*, lyre-like excavation of base of lingula; *m. n. p.* the three points of the left superior lobe.

Fig. 118. *Crioprora cyanella;* (*315), ventro-cephalic view of genitalia. *a*, cephalic claw from left superior lobe; *b*, termination of ejaculatory duct; *c*, right internal lobe; *d*, chitinous box; *e*, apical lobe of ejaculatory hood; *f*, caudal lobe of right style; *g*, cephalic lobe of right style. The vestiture of styles and lobe is not shown.

Fig. 119. *Milesia virginiensis;* ventro-cephalic view of genitalia (*319). *a*, thinly chitinized, apical portion of the superior lobe.

Fig. 120. *Somula decora;* cephalic view of left style and penis (*306). *a*, erect, caudal lobe of style; *c*, the baso-lateral prolongation to the tenth tergite; *b*, *b*, cephalic lobe of style which approaches the one of the right style, caudad of the penis; *k*, sinuate keel at sides of penis-sheath to basal prominence above articulation of tergite ten (*d*).

PLATE XIX.

Fig. 96. *Teuchocnemis litturatus;* distal view of genitalia (*238). *a*, apical hook of styles; *b*, keel on lateral face of styles; *c*, cephalic lobe of styles.

Fig. 97. *Pterallastes thoracious;* ventro-cephalic view of genitalia (*241). *a*, blunt, median thumb of inferior lobe; *b*, lateral finger of inferior lobe; *c*, lingula with a small V-shaped notch at apex; just above the notch is seen the small aperture of the ejaculatory duct; *e*, caudo-distal hooks of superior lobes; *f*, cephalo-distal hooks of superior lobes; *g*, swollen basal plate, forming baso-cephalic part of superior lobes.

Fig. 98. *Teuchocnemis litturatus;* left style in lateral view. Captions as in Figure 96.

Fig. 99. The same, right style in lateral view. Captions as in Figure 96.

Fig. 100. The same, genitalia in cephalic aspect; *d*, termination of ejaculatory duct. Other captions as in Figure 96.

Fig. 101. *Pterallastes thoracicus;* genitalia from the right side. *d*, small thorn at base of superior lobes.

Fig. 129. *Microdon tristis;* ventro-lateral view of genitalia (*423). *a*, *a*, caudal part of basal rim of penis; *b*, infolded caudal margins of the penis sheath, which is not continuous on the caudal surface; *c*, hairy prominence on lateral margin of tenth sternite; *d*, caudal lobe of style; *e*, cephalic lobe of style.

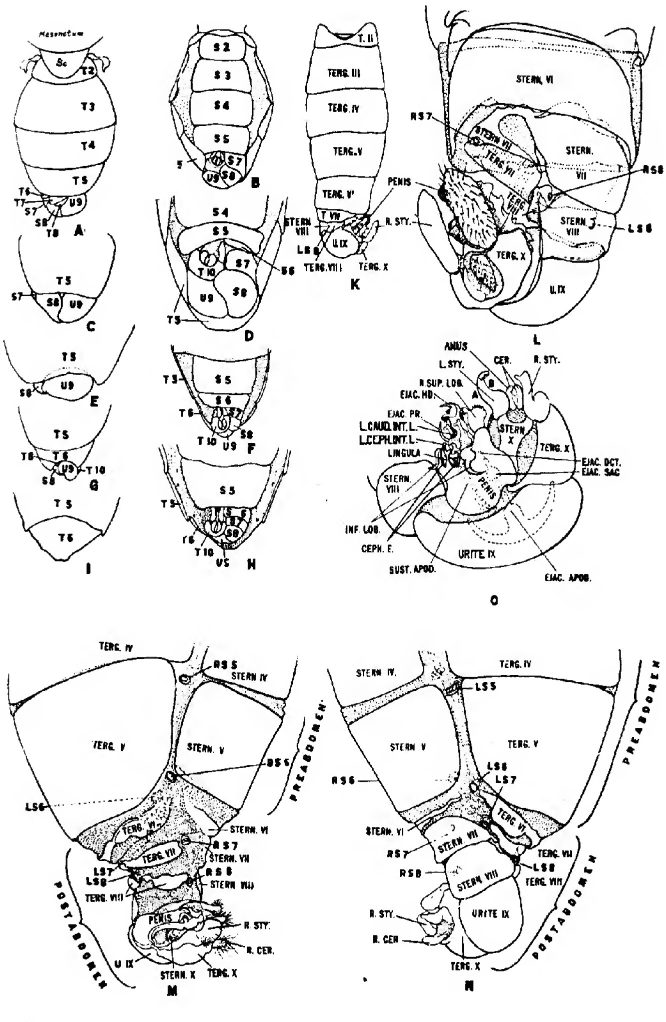
Fig. 130. *Microdon fuscipennis;* ventro-cephalic view of genitalia (*423). *f*, hairy concavity on lateral surface of tenth tergite. Other captions as in Figure 129.

Fig. 131. *Ceriodes tridens;* ventro-cephalic view of genitalia (*317).

Fig. 132. *Ceriodes abbreviata;* ventro-cephalic view of genitalia (*316).

Fig. 133. *Mixogaster breviventris;* ventro-cephalic view of genitalia (*159).

Fig. 134. *Eupeodes volucris;* ventro-lateral view of posabtdomen and genitalia (*153). The penis has been separated along the line *b* from the mesal margins of segments VI, VII and VIII; *a*, disto-ventral projection of slender basal part of tenth tergite; *b*, left side of basal rim of penis; *c*, horny disto-lateral keel of penis-sheath; *d*, cephalic face of penis-sheath; *e*, caudal face of penis-sheath; *f*, depression of sternite vi. to form a shallow genital pouch.



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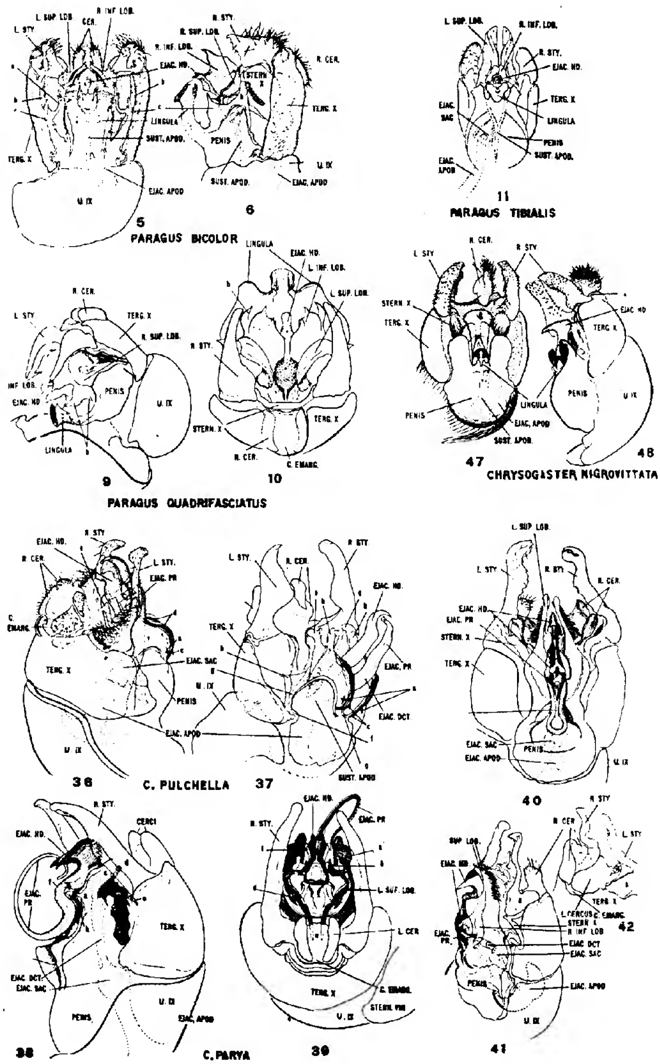

5 6 PARAGUS BICOLOR

11 PARAGUS TIBIALIS

9 10 PARAGUS QUADRIFASCIATUS

47 48 CHRYSOGASTER NIGROVITTATA

36 C. PULCHELLA 37

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38 C. PARVA 39

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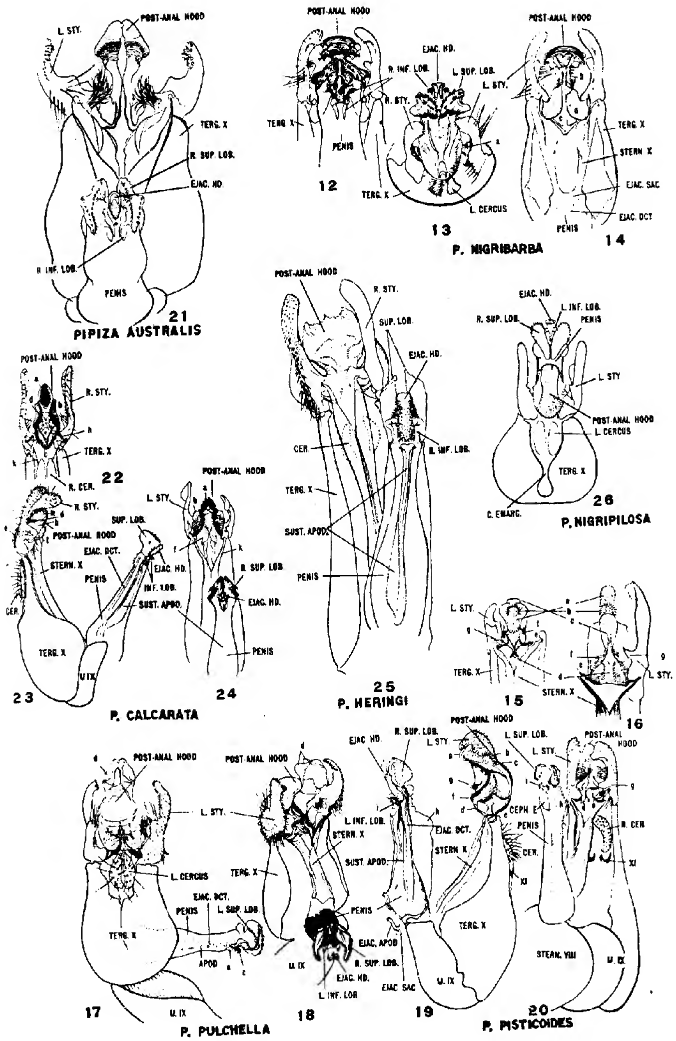
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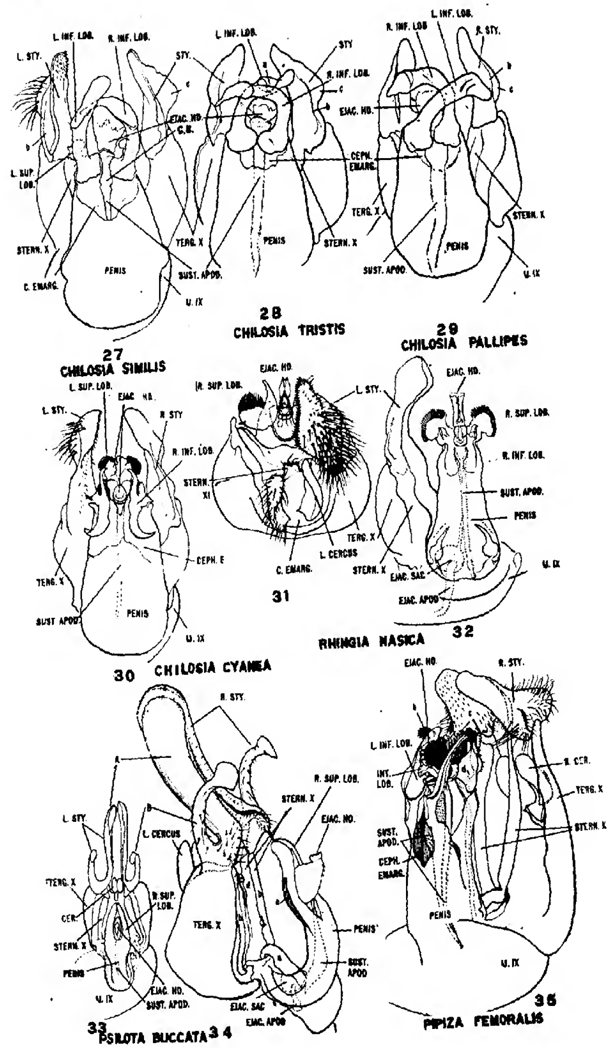
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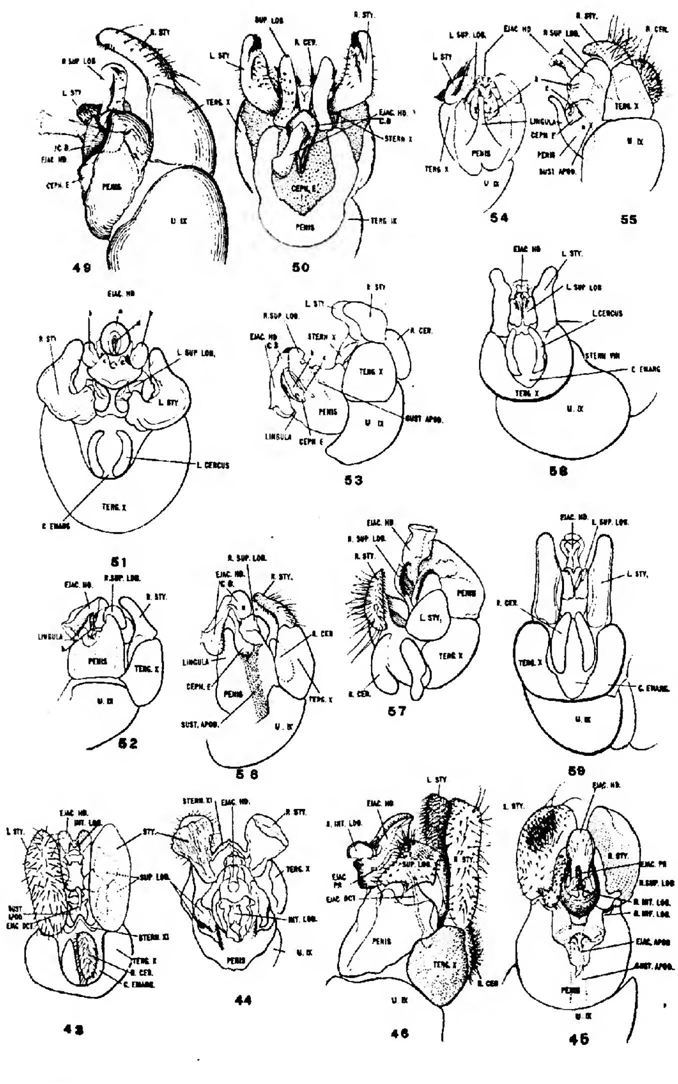
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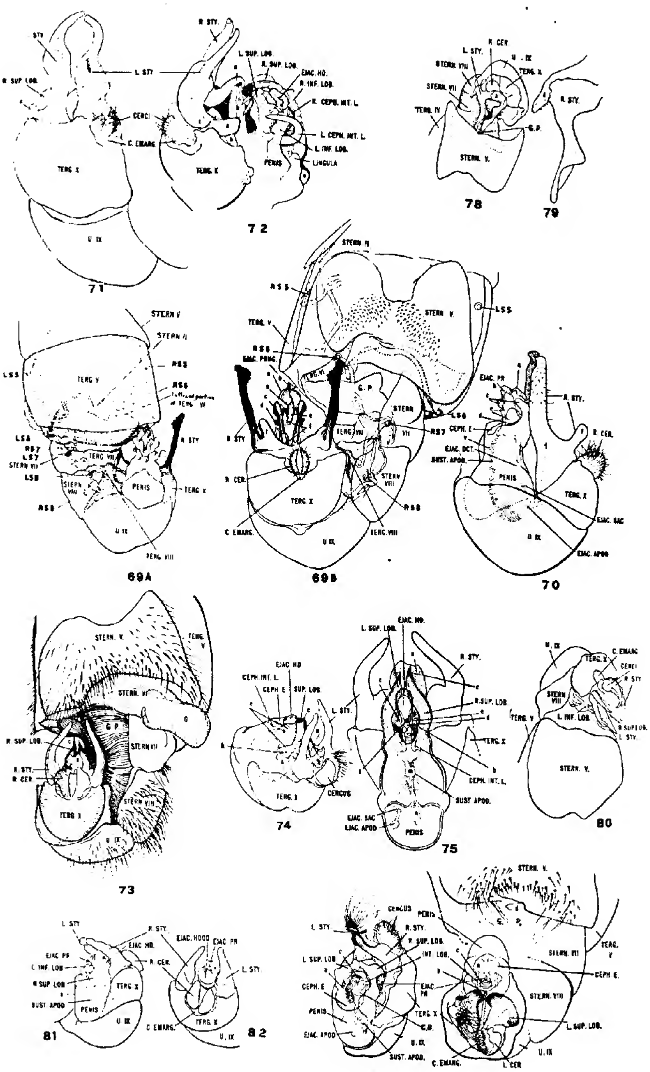

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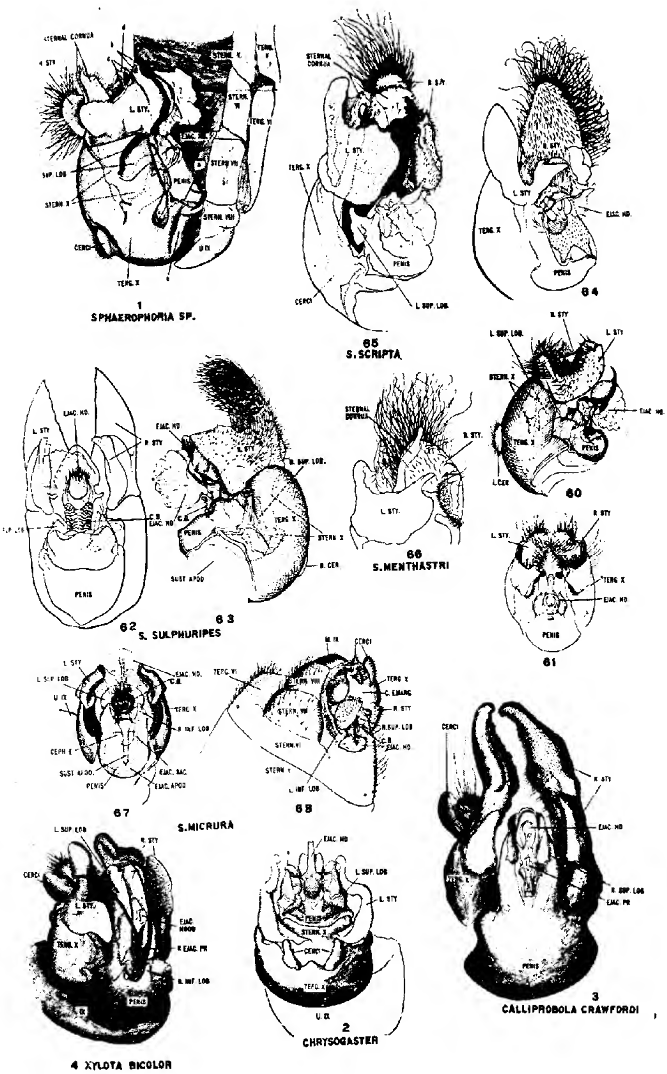
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CALLIPROBOLA CRAWFORDI

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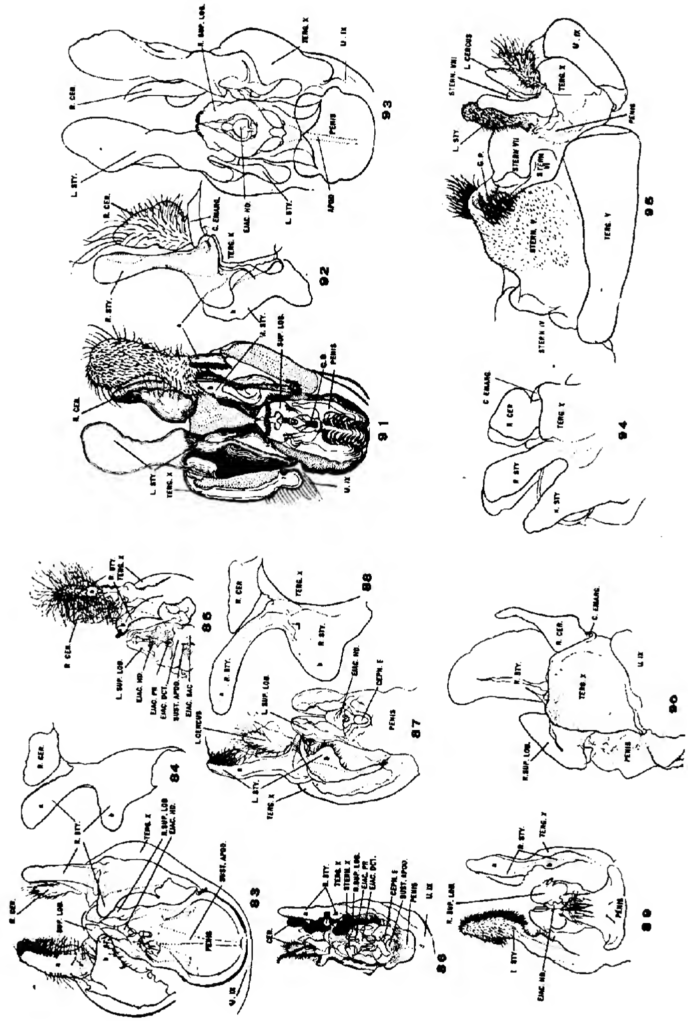

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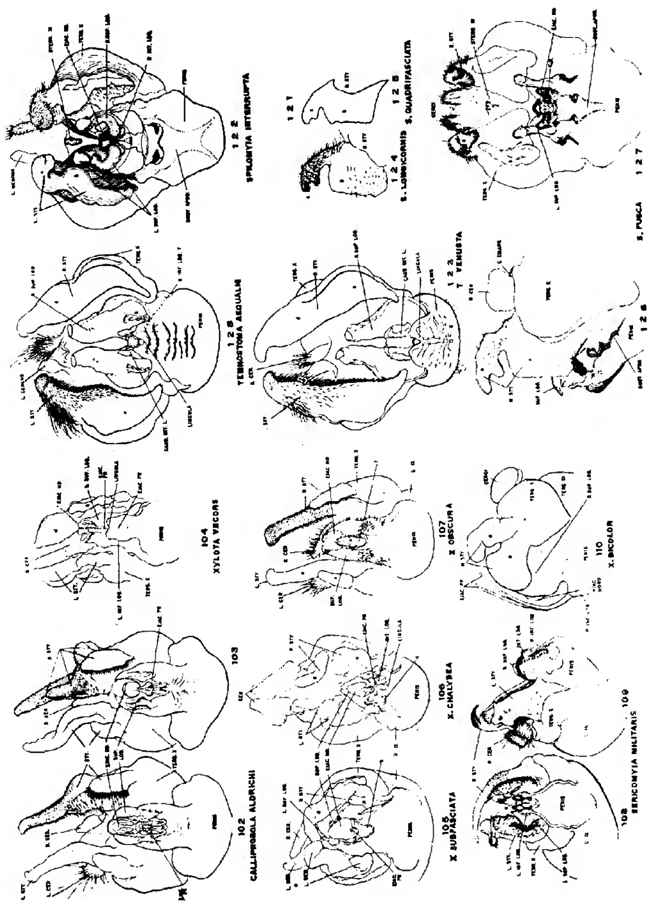
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106 X. CHALYBEA
107 X. OBSCURA
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110 X. BICOLOR
120 TEMNOSTOMA AEQUALIS
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122 SPILOMYIA INTERRUPTA
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124 S. LONGICORNIS
125 S. QUADRIFASCIATA
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127 S. FUSCA

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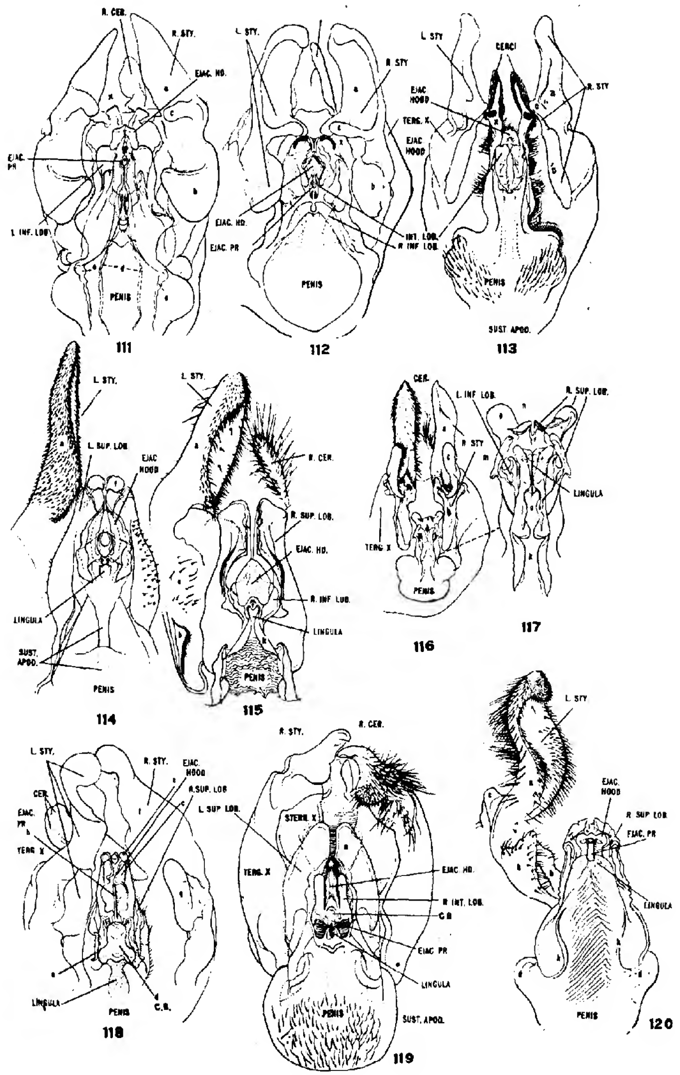

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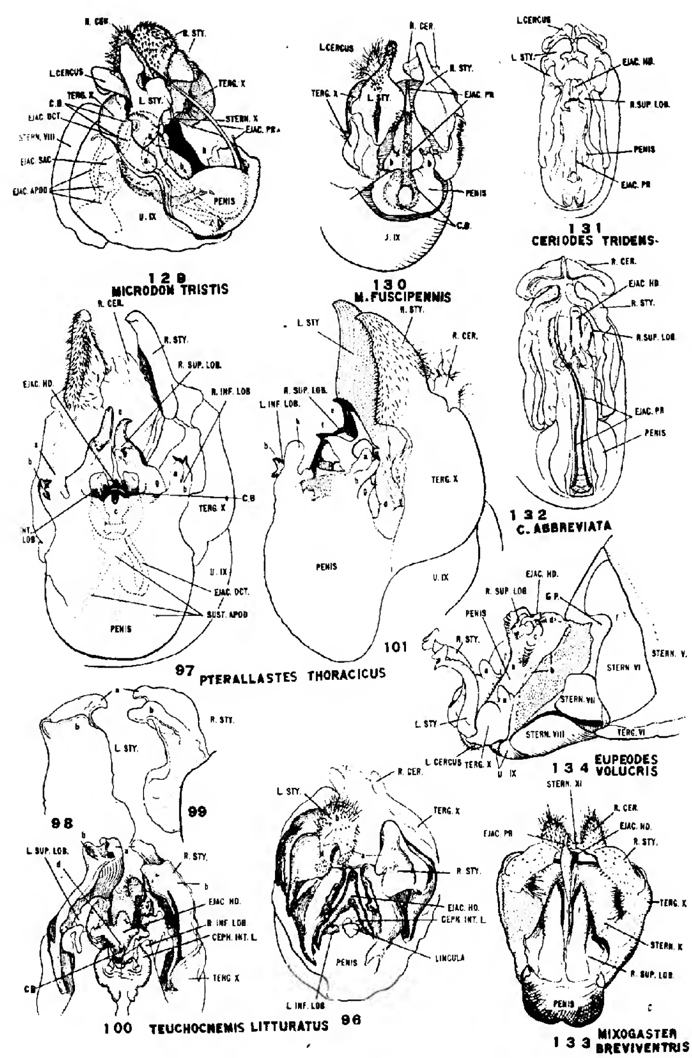
C. L. Metcalf.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101
134 EUPEODES VOLUCRIS
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100 TEUCHOCNEMIS LITTURATUS 96
133 MIXOGASTER BREVIVENTRIS

C. L. Metcalf.

A METHOD FOR STUDYING THE HESSIAN FLY AND OTHER INSECTS.*

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The following method for conducting life history studies was developed in connection with a study of the Hessian fly (*Mayetiola destructer* Say) and since then has been used for making detailed observations on the development of several other insects attacking the stem and leaves of various cereal crops. The fact that the Hessian fly larvæ develop between the leaf sheath and the stalk often below the surface of the ground has rendered it difficult to follow the growth of this stage. It has also been hard to observe the development of the eggs and the behavior of the larvæ on the leaf.

In 1916, an attempt was made to grow the wheat plants in an artificial culture medium so that the entire plant would be exposed and accessible for observation.† Plant physiologists have long made use of water cultures in conducting experiments on the nutrient requirements of plants and other physiological relations and it seemed possible that with certain modifications this method could be extended to observations on insect life histories. In the Hessian fly investigations, the wheat was planted in soil or sand and allowed to grow to a height of two or three inches. The plants were then removed from the soil, the roots thoroughly washed to remove all soil particles, and then placed in wide-mouth bottles of 200 cc. capacity, containing about 150 cc. of the water culture (Fig. 1). One plant was placed in each bottle, the roots being immersed in the liquid and the stalk kept in position by being held lightly against one side of the neck of the bottle with a cotton stopper. The liquid

* Contribution from the Entomological Laboratory, Kansas State Agricultural College, No. 52. This paper embodies the results of some of the investigations undertaken by the writer in the prosecution of project No. 6 of the Kansas Agricultural Experiment Station.

† The writer wishes to acknowledge his indebtedness to Mr. H. Yuasa for suggestions and aid in connection with this work.

plant food used was that known to plant physiologists as Pfeffer's solution and is prepared as follows:

Calcium nitrate	4 grams
Potassium nitrate	1 gram
Magnesium sulphate	1 "
Potassium dihydrogen phosphate	1 "
Potassium chloride	0.5 "
Ferric chloride	Trace
Distilled water	3 to 7 liters*

The plants grew well in this solution, although at times some difficulty was encountered by the growth of algæ in the liquid. This was largely overcome, however, by painting the bottles black. Usually the plants lived long enough for experimental purposes without changing the liquid. When the experiments were prolonged the solution was changed as often as necessary.

By using this method, it was possible to follow the life history of the Hessian fly from oviposition to the formation of the puparium. The plants could be handled conveniently and the various stages studied with greater ease and exactness than when the plants were grown in the soil. When necessary, the plants could be removed from the bottle and placed under the binocular for close study. By carefully shaving the epidermis of the leaf sheath, it was possible to keep the larvæ under observation at all times. As the larvæ increased in size they could readily be seen through the neck of the bottle.

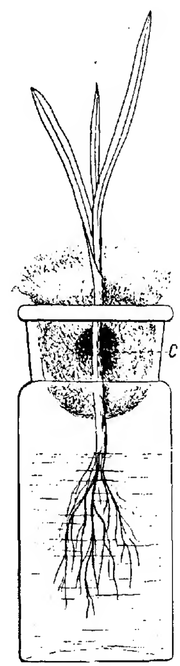

FIG. 1.
Wheat plant growing in a nutrient solution.
C—Cell for confining insects on the plant.

This method proved so successful in the Hessian fly work that it was adopted for the study of a number of other insects infesting cereal crops. Thus far the writer has grown wheat, oats, rye, barley, corn, and many of the sorghums in Pfeffer's solution in connection with studies of the chinch bug (*Blissus leucopterus* Say), green

* The writer has found that five liters is best for the work under consideration.

bug (*Toxoptera graminum* Rond) and corn leaf aphis (*Aphis maidis* Fitch).

Certain modifications in the method of handling the plants were necessary for these insects. In order to confine them on the stalks of the plants, a small cell was formed in one side of the cotton stopper (Fig. 1-c). The cotton fibers served as effective barriers in holding the insects in the cell and exact data could be obtained on molting and the length of instars, and, in the case of the aphids, on the number of young produced. This method was also used to study certain phases of activity of several parasites of the Hessian fly puparium. The parasites were confined in the cells with plants containing flaxseed in their natural position and the behavior and methods of oviposition of the parasites were easily observed. In a similar manner a study was made of the chinch bug egg parasite (*Eumicrosoma benefica* Gahan). Good results were obtained in confining leaf-feeding insects on the leaves by inverting another bottle over the plant or by lowering the plant so as to bring a part of the leaf into the cell.

In conclusion, a brief summary is given of the more important advantages of this method of growing plants for life history studies.

1. By certain modifications this method may be enlarged to facilitate more extended observations on a much larger number of insects.

2. The manipulation of plants in a water culture has proved very satisfactory in growing most of the staple crops, it being easily done and facilitates handling the plants in making close observations.

3. This method is especially valuable where the work is done under constant conditions, since it eliminates the factor of variation in plant food.

4. The use of the water culture enables one to study many phenomena in the insect's life history that normally are difficult to observe and which often necessitate the destruction of the plant.

5. When plants are grown by this method, they may be removed and examined under the microscope or binocular without injury to the plant.

6. Plants are often found in the field infested with some insect which it is desirable to rear to maturity. Such plants can be removed from the soil and kept alive in a water culture until the insect matures.

7. Many points in the life economy of parasites may be studied in detail with relation to the host.